ERDC/EL TR-07-28

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Yuma Proving Ground GEM-3-E Data Collection

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Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Restoration Requirement A (1.6.a), UXO Screening, Detection, and Discrimination

Abstract: This report documents the performance and operational capabilities of the GEM-3 system for the Advanced UXO Detection/Discrimination Technology Demonstration at the U.S. Army Yuma Proving Ground (YPG), Yuma, AZ. The data collection effort was conducted under the Department of the Army Research and Development DOBE4 (BA4) Technical Demonstration Program. Data analysis was conducted under the Department of the Army Research and Development DOE3 (BA3) Program. The objective was to evaluate the enhancements made to the GEM-3 system. Post-demonstration analysis focused on the functionality of the sensor system, the evaluation of the noise level of the data collected, improvements in target detection and discrimination, and positioning accuracy of the system. The stability of the system was evaluated through histograms and statistical analysis of data collected during the technology demonstration. Based on findings of the characteristics of the collected data and initial work performed on target detection and discrimination, target detection and discrimination techniques were applied and evaluated.

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Preface

This report describes the efforts conducted under the sponsorship of the Environmental Quality Technology (EQT) Program A (1.6.a), Unexploded Ordnance (UXO) Screening, Detection, and Discrimination Management Plan, Test and Evaluation (BA4), Major Thrust Area II, UXO Technology Demonstration, Work Unit "Hand Held UXO Detector, Design, Demonstration and Validation." The work documented in this report was performed during the period 6–24 May 2003. This project was funded through the EQT Program. Dr. M. John Cullinane, Jr., was Technical Director, Military Environmental Engineering and Science, Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), for EQT UXO work.

John H. Ballard, EL, ERDC, and George Robitaille, U.S. Army Environmental Center (USAEC), were program managers for EQT UXO BA2/3 and BAA programs, respectively. Hollis "Jay" Bennett, Jr., ERDC, EL, was Principal Investigator and was responsible for planning, participated in the execution of field demonstration activities, and directed the analysis of the results. Ricky A. Goodson, Charles D. Hahn, Morris P. Fields, and John Cliff Morgan, ERDC, EL, executed the field demonstrations. Fields was responsible for the daily log records. Bennett, Fields, Goodson, Morgan, and Tere A. DeMoss, EL, and R. Eddie Milton, JAYA, assisted with data analysis. The review and recommendations provided by Aberdeen Test Center (ATC) located at Aberdeen Proving Ground (APG) are gratefully acknowledged.

This project was performed under the general supervision of Dr. David J. Tazik, Chief, Ecosystems Evaluation and Engineering Division, EL, and Dr. Beth C. Fleming, Director, EL.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

This report documents the performance and operational capabilities of the GEM-3 system for the Advanced UXO Detection/Discrimination Technology Demonstration at the U.S. Army Yuma Proving Ground (YPG), Yuma, AZ. The data collection effort was conducted under the Department of Army Research and Development DOBE4 (BA4) Technical Demonstration Program. Data analysis was conducted under the Department of Army Research and Development DOE3 (BA3) Program. This project addressed the Environmental Quality Technology (EQT) Program thrust area entitled "UXO Technology Demonstration," Work Unit "UXO Detection Design Demonstration and Validation." The work described herein was conducted under Task 1 of this work unit. The objective was to evaluate the enhancements made to the GEM-3 system. Post-demonstration analysis focused on the functionality of the sensor system, the evaluation of the noise level of the data collected, improvements in target detection and discrimination, and positioning accuracy of the system. The stability of the system was evaluated through histograms and statistical analysis of data collected during the technology demonstration. Based on findings of the characteristics of the collected data (Cespedes 2001, ERDC 2002) and initial work performed on target detection and discrimination (Miller et al. 2001), target detection and discrimination techniques were applied and evaluated.

Standardized UXO technology demonstration site

The YPG standardized UXO technology demonstration site is located within a secured range area of YPG (see Figure 1). YPG is located adjacent to the Colorado River in the Sonoran Desert, about 29 miles from Yuma. The Standardized UXO Technology Demonstration Site is located south of Pole Line Road, and east of the countermine testing and training range (see Figure 2). The open field range, calibration grid, blind test grid, mogul area, and desert extreme area comprise the 350 by 500 m general test site area. The open field site is the largest of the test sites and measures approximately 200 by 350 m. To the east of the open field range are the calibration lanes and blind test grids (BTG) that measure 30 by 40 m and 40 by 40 m, respectively. South of the open field is the 135 by 80 m mogul area consisting of a sequence of man-made depressions. The desert extreme area is located southeast of the open field site and is 50 by 100 m.

Figure 1. Photo of standardized UXO technology demonstration site.

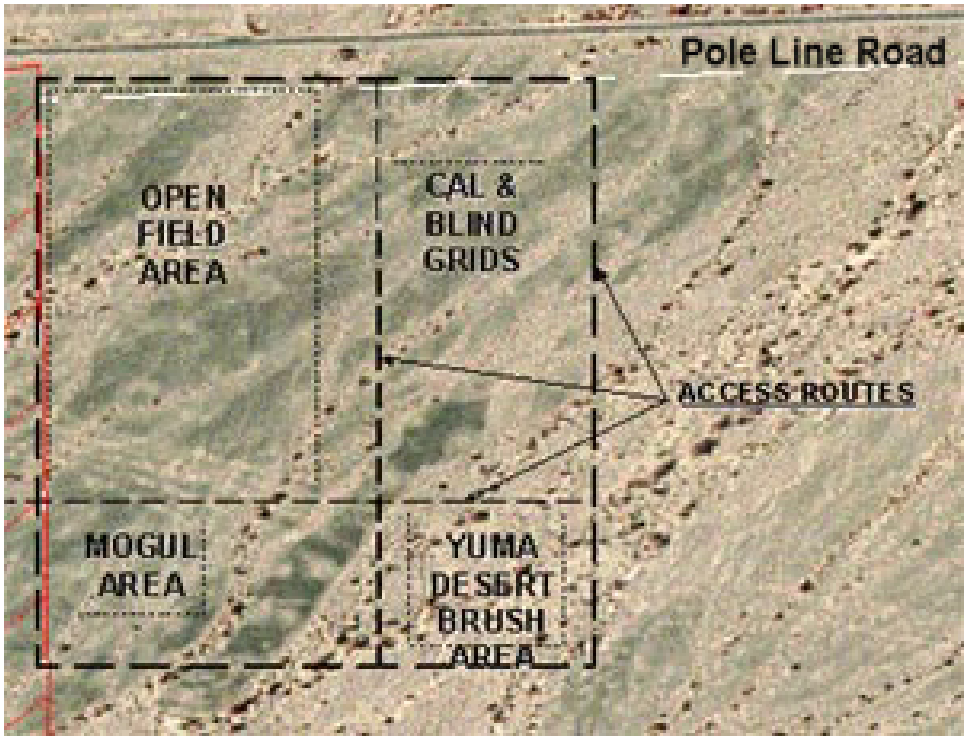

Figure 2. Overlay map of standardized UXO technology demonstration site.

The desert extreme area, covered with desert-type vegetation, is used to test the performance of different sensor platforms in a more severe desert condition/environment. The layout description includes the following:

1. Blind test grid – 0.17 hectare (0.43 acre)
2. Calibration lanes – 0.11 hectare (0.27 acre)
3. Open field – 6.22 hectares (15.38 acres)
4. Scenario 1. Moguls – 1.07 hectares (2.64 acres)
5. Scenario 2. Desert Extreme – 0.50 hectare (1.23 acres).

Description of data collection equipment

The GEM-3-E, manufactured by Geophex, Ltd., is a multi-frequency frequency domain electromagnetic (FDEM) system (Won et al. 1997). The GEM-3 sensor head contains three concentric coils. The outer coil (TX) is used as a transmitter, an inner low power transmitting coil is a bucking coil (BX) that is used to create a null area, and the innermost coil, located in the null area, is used as a receiver coil (RX) (see Figure 3). The null area allows induced radiation returning from the target to be measured by the RX coil. Hence, the two transmit coils create a central magnetic cavity producing zero output to the inner receiver coil. For frequency-domain operation, the GEM-3 prompts for a set of desired transmitter frequencies. Built-in software converts this into a digital "bit-stream," which is used to construct the desired transmitter waveform. This bit-stream represents the instruction on how to generate a complex waveform that contains all frequencies specified by the operator. The basic GEM-3 Package consists of a 96-cm-diameter sensing head, handle boom, console with display unit, battery, and a battery charger. Standard data acquisition software includes WinGEMv3, a Windows-based operation software which allows the operator to control the instrument, merge the global positioning system (GPS) stream into the data, and store the data.

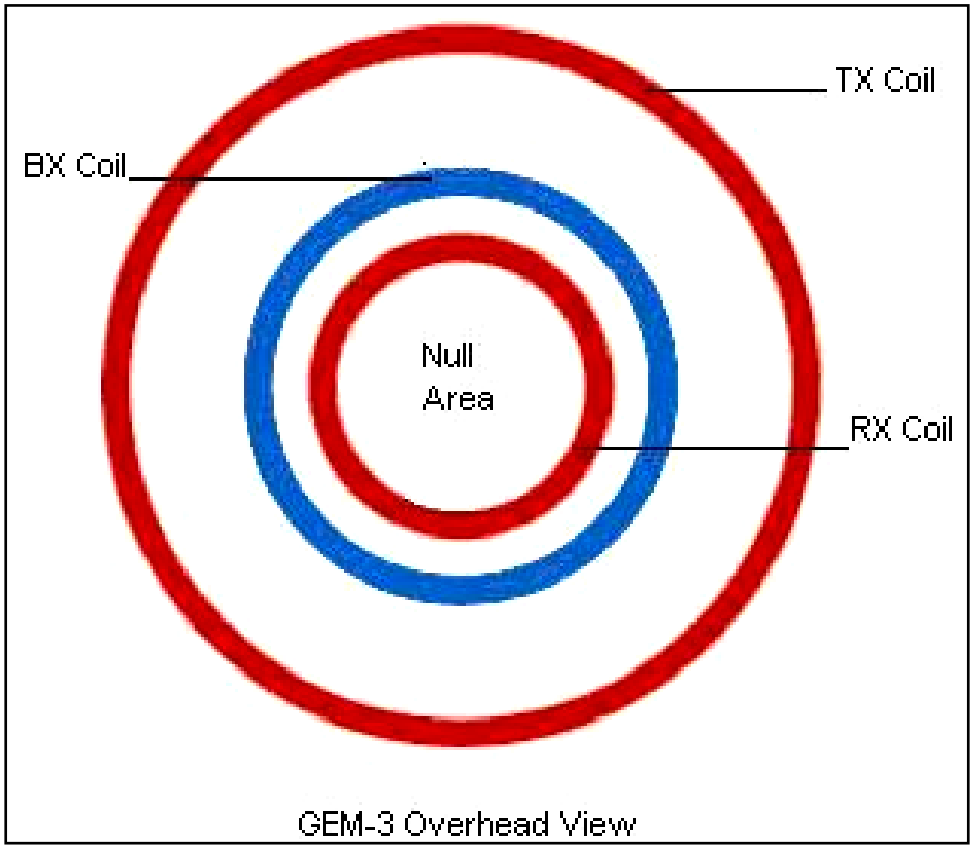

Figure 3. Schematic diagram showing internal construction (three concentric coils) of the GEM-3-E.

2 Standardized UXO Technology Demonstration Site

Areas and grids of the standardized UXO technology demonstration site

The calibration portion of the test site consisted of 19 lanes. Seventeen of these lanes contained six identical munitions buried in various orientations and at three different depths. One lane contained four steel spheres, 8-lb shotput (8-lb Shot) buried at a depth of 0.5 to 2 m. Another lane contained two each (30.48- and 60.96-cm diameter) circular steel plates buried at 30.48 and 91.44 cm, respectively. A third lane contained 15- and 30-cm diameter copper wire loops (12, 16, 18, and 20 gauge) buried at 0.3 m depth. These wire loops, which give a standard signature, were used to calibrate the detection signatures received by the instrument. Munitions that are generally rectangular in shape (aspect ratio not equal to one) were buried in the ground in six orientations and at three different depths. Munitions that are generally round in shape (aspect ratio of one) were buried at three different depths. A 3.6-kg steel ball (diameter is 8.9 cm) was buried at a depth of 15 cm at the end of the calibration lanes to provide a uniform signature that could be easily identified when examining the raw data.

The YPG BTG, as shown in Figure 4, consists of a 1,600-m^2 area that is located east of the open field range. The BTG was composed of the same type of munitions found in the calibration lanes and open field site. Clutter items included intentionally buried non-UXO targets such as metal, scrap, wood, and rocks.

The open field test area is the largest test area at the YPG Standardized UXO Technology Demonstration Site and measures approximately 200 by 350 m (15.38 acres). The area proved beneficial in providing a variety of realistic scenarios for evaluating sensor system performance of the GEM-3-E. The main challenges include open areas, dips, ruts, electrical lines, metallic fencing, desert extreme, stone pads, and roadway areas. There are virtually thousands of grid cells within the open field area, and at the center of each grid cell there is either ordnance, range clutter, or nothing at all.

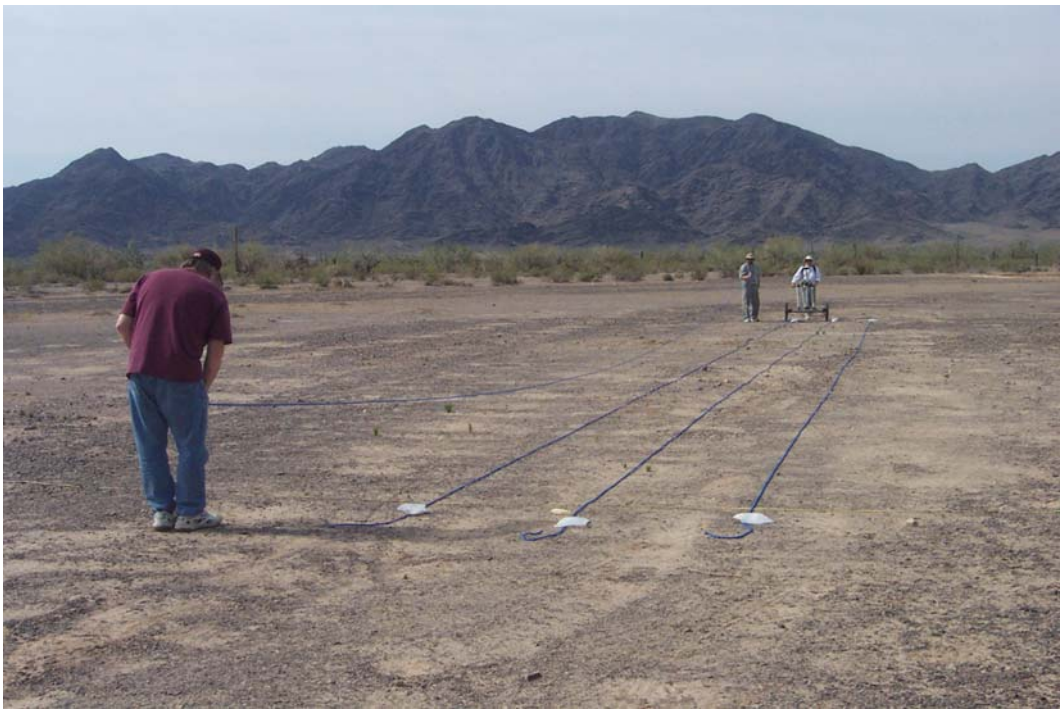

Figure 4. The blind grid area at YPG.

The mogul area (see Figure 2) consisted of two areas: (1) the rectangular or driving portion of the course and (2) the triangular section with more difficult, non-drivable terrain. The rectangular section included six test lanes, which incorporate a slope challenge, 0.61-m and 0.91-m moguls, 0.61-m and 0.91-m slanted moguls, and vibration lanes. This section of the course challenged the GEM-3-E cart's ability to traverse adverse terrain. It was also used to check accuracy of sensor equipment when subjected to vibration and offset angles that resulted from rough terrain. The triangular section incorporated more intense moguls and terrain, which can only be traversed by hand-held or man-portable cart-mounted sensor devices. A series of craters (as deep as 0.91m) and mounds (as high as 0.91m) encompassed this section.

The desert extreme portion of the test site consists of a 50 by 100 m area that is located southeast of the open field test site (see Figure 2). The area, covered with desert vegetation, was used to evaluate the performance of the GEM-3-E's sensor platform in a more severe desert environment. The soils in this region generally consist of calcium carbonate materials that tend to cement together in the soil, producing hard layers in the subsurface. Ground temperature in this region reached up to 160 °F in early afternoon. Air temperatures in shaded areas often exceeded 110 °F.

Weather conditions

The YPG area year-round records show that on average, Yuma receives approximately 4,133 hr (93% of annual hr) of sunshine annually. Yuma is in a desert environment, and temperatures generally average above 100 °F for the summer months. In the extreme desert region, ground temperature can reach up to 160 °F by early afternoon. However, dry air (low relative humidity) tends to make the days feel cooler and more comfortable than comparable temperate areas with higher relative humidity. During evening hours, evaporative cooling dramatically reduces the temperature.

Table 1. Data summary.

Average precipitation (inches per year)	3.43
Monthly average temperature	75.2 °F (24 °C)
Relative humidity – 11 a.m., July	32%
Elevation above sea level (feet)	138

Field conditions

Personnel of the ERDC surveyed the BTG on 10 May 2003. The weather condition during the data collection for the first week was cloudy and cool in the morning. For the last two weeks of the study (17-31 May), the conditions at YPG were hot and sunny with temperatures reaching 110 °F. A lack of precipitation in this area produced extremely dry field conditions (Figure 5). Gusting winds made data collection and marking of the survey grid with nylon lines very difficult during the first week (10-16 May).

Soil analysis

Soil samples were collected at the YPG Standardized UXO Test Site to characterize the shallow subsurface (< 3 m) (see Appendix C). Both surface grab samples (15) and continuous soil borings (13) were acquired. Soil laboratory analyses included sieve/hydrometer, water content, magnetic susceptibility, dielectric permittivity, x-ray diffraction, and visual description. Tables with Aberdeen Test Center (ATC) laboratory soil test results are provided in Appendix C.

Figure 5. Area weather is arid and warm.

There are two soil complexes present within the site, Riverbend-Carrizo and Cristobal-Gunsight. The Riverbend-Carrizo complex is comprised of mixed stream alluvium, whereas the Cristobal-Gunsight complex is derived from fan alluvium. The Cristobal-Gunsight complex covers the majority of the site. Most of the soil samples are classified as either a sandy loam or loamy sand, with most samples containing gravel-size particles. An x-ray diffraction analysis was conducted on four soil samples and determined that the basic mineralogy consists of quartz, calcite, mica, feldspar, magnetite, and some clay. The soils in the extreme desert region may have a horizon of calcium carbonates that tend to cement together in the soil, producing hard layers in the subsurface. The presence of magnetite imparts a moderate magnetic susceptibility, with volume susceptibilities generally greater than 1.00×10^{-3} SI.

Field activities

Setup/mobilization

Setup/mobilization activities included initial mobilization, daily equipment preparation, and demobilization. A four-person crew took 4 hr 45 min to perform the initial setup and mobilization. Daily equipment preparation took approximately 1 hr. Daily battery changes and data

downloading activities totaled 1 hr for the BTG. The ERDC team constructed a calibration test pit, a hole 1 m by 0.5 m by 1 m (length, width, and depth), to allow the collection of signature data of all items with various orientations.

Calibration

Personnel of the ERDC collected data for approximately 2 hr in the calibration lane on 9 May. Data were also collected in the calibration test pit on 11 May using the 14 standard inert ordnance targets as shown in Figure 5. No other calibration activities were performed while surveying the BTG.

Equipment/data checks, maintenance

Equipment/data checks and maintenance activities accounted for approximately 10 min of site usage time in the BTG.

Equipment failure or repair

No equipment failures occurred while the ERDC team surveyed in the BTG. However, problems were experienced with the prototype man-portable pushcart in the open field test area. The nylon bolts used to anchor the wheels to the platform became stripped after minimal use. This equipment failure accounted for 50 min of downtime on 9 May. The problem was initially corrected by replacing the nylon bolts. The first week involved repeated tightening of the nylon bolts until the equipment experienced complete failure using nylon bolts. During week 2, corrections were made using an assortment of improvised non-metal devices that were procured from a local hardware store.

3 System Descriptions

GEM-3-E system description

The GEM-3-E is a broadband, programmable electromagnetic (EM) sensor. The GEM-3-E consists of a circular sensor, a three-button user interface or Personal Data Assistant graphical interface, an electronics console, and WinGEM software. The sensor is available in three different sizes. The 40-cm and 64-cm sensors come mounted on booms for handheld operation; whereas, the 96-cm sensor is usually mounted on a wheeled cart.

System specifications GEM-3-E

- Multiple-frequency operation: up to 15 frequencies
- Frequency band: 330 to 47970 Hz
- Coil configurations: horizontal coplanar
- Battery: standard 12-volt notebook computer battery (B905S)
- Battery life: ~4 hr
- Weight: 9 lb (4 kg)
- Basic output: in-phase and quadrature response in parts per million (ppm)
- PC software: WinGEM2k
- Positioning: Utilizing real-time GPS data

System configuration GEM-3-E

The GEM-3-E cart system as used at YPG consisted of the 96-cm head with the data acquisition box, and a Trimble 4700 GPS rover. The GPS rover was removed from the backpack and secured to a mast centered above the GEM-3-E sensor head of the GPS antenna. The controller box was attached to the GEM-3-E adjacent to the Hewlett Packard Palm computer (iPAQ), where the operator could monitor the validity of the positioning data (see Figure 6). Frequency data were collected simultaneously for 90, 210, 390, 750, 1470, 2910, 5850, 11430, 21690 and 41010 Hz.

Figure 6. The GEM-3-E cart system with controller and GPS.

Positioning system

System specifications

Real-Time Survey Performance (Requires Trimble handheld survey controller model TSC1™ with Trimble Survey Controller™ software.)

- Modes: Real-time stop-and-go, Real-time continuous
- Precision:

Modes	Latency	Accuracy
1 Hz fine	0.4 sec	±1 cm + 2 ppm Horizontal
		±2 cm + 2 ppm Vertical
5 Hz fine	0.1 sec	±3 cm + 2 ppm Horizontal
		±5 cm + 2 ppm Vertical

- Coarse 20 cm RMS
- Range: Up to 10 km, depending on radios used

Initialization

- Type: Automatic while moving (on-the-fly [OTF]) or static
- Typical Reliability: 99.9%
- Time: <1 minute typical

General performance

- Tracking: 9 channels (12 channels for CORS system only)
- L1 C/A code, L1/L2 full-cycle carrier
- Fully operational during P-code encryption
- Data logging: Data are logged internally (Additional data storage in the TSC1 or on the optional removable PC cards available for the TSC1)
- Internal Data Storage: 120 hr of L1/L2 data while tracking six satellites at standard output 15-second epoch interval
- Standard Input/Output: RTCM SC-104 input version 2.1
- NMEA-0183 Navigation output

Internal receive only radio modem performance (requires internal radio modem)

- Modes: High gain UHF
- Range: Base Radio Modem
- TRIMTALK™ 450S TRIMMARK™ IIe
- Optimal: 10 km 15 km
- Typical: 3–5 km 10-12 km
- Radio Modem:
- Freq. Range: 410-420 MHz, 430–440 MHz, 440–450 MHz, 450–460 MHz or 460–470 MHz (only one per model)
- Channels: Up to 20 (factory pre-set)
- Channel Spacing: 12.5 KHz or 25 KHz (only one per system)
- Wireless Data Rates: 4,800 and 9,600 bps
- Modulation: GMSK

System configuration

Real-time kinetic (RTK) GPS positioning was collected using a Trimble Pathfinder 4700 series rover and base station for differential GPS (DGPS). With the rover GPS system (receiver and antenna) mounted on a mast located 1.5 m above the center of the head on the GEM-E unit, there was no offset correction required. The moving accuracy of the DGPS for this system was on the order of 2 cm. However, due to the rotation of the mast

above the wheels, errors of 10 cm or greater were experienced. Positional data were logged simultaneously in the GEM-3-E data acquisition console and the Trimble data logger.

4 Data Collection Procedure

Survey setup

Data were collected over the calibration lanes and the BTG areas. These areas have lanes designating the possible locations of targets. Additionally, these lanes are marked with sections of PVC pipe driven into the ground at 1-m intervals. A 50-m tape was laid at both ends of the areas to designate the line spacing. Also, nylon lines were laid out between the tapes to measure 2-m intervals. By lining up with the wheels alternating either on the line or straddling it, the operator was able to collect data at ½-m spacing. Data collected between two lines at the ½-m mark are shown in Figure 7.

The open field area was subdivided into smaller grids so that data could be acquired in more manageable segments. Typically a 100-m grid was selected, but there were exceptions due to site topography. Ropes were stretched between surveyed points to create gridded lanes over this area in a manner similar to the BTG and calibration areas. Data in this grid were collected in segments and downloaded. During the break, lane marker ropes were moved.

These data would then be reviewed for QA/QC. If there was a problem data were corrected in a timely manner. A similar procedure was used in the desert extreme. Although the moguls were divided into two areas, they were acquired in a single grid.

Quality assurance/quality control procedures

There were a number of standard measures that the ERDC team used to ensure the quality of the data collected during the field investigation. Inspection of coverage maps was the first step. The data were corrected for GPS drift and viewed in pseudo three-dimensional (3-D) to look at the quality of the sensor positioning response. Statistical analysis was also performed on the data, and calibration source responses were analyzed to quantify data drift.

Figure 7. The GEM-3-E with ropes marking survey grid lines.

Coverage maps

The first QA/QC function was to examine the spatial distribution of the acquired data to ensure that the survey area was adequately covered. After each data acquisition event and upon data being downloaded, a line path plot was generated delineating the collected data. This method of data visualization was used to verify that no significant gaps were present in the newly acquired data or between the new data and the previously acquired data. When all the data for an area were collected, a coverage map of the area was generated using the Geosoft UX-Detect software module. A grid of a user-selected ground resolution was created and the survey points that pass through each grid are counted and displayed on a color-coded map. Grid cells with a value of zero, which is displayed in white, indicate gaps in area coverage at the resolution being displayed. A coverage map was generated for each instrument at two resolutions: 0.5 m, which was the nominal line spacing for this data collection, and 0.75 m. If the survey lines were walked perfectly and no positioning error was present, then the 0.5-m coverage map would show 100% coverage. Due to imperfections in the data acquisition process, some small gaps in coverage may appear in the 0.5-m coverage maps; however, these gaps should disappear in the 0.75-m coverage map. Gaps in the 0.75 m coverage map would indicate

significant departures from the desired sampling coverage. Coverage maps are discussed in more detail in Chapter 5.

GPS corrections

GPS data were collected using a Trimble Pathfinder 4700 series rover and base station for differential GPS. In this configuration, the accuracy is between 2 and 10 cm.

Due to an internal lag between the synchronization of the input port on the GEM-3-E and the output of the DGPS system, it was necessary to correct the merged data stream to insure that the position data and the measured electromagnetic data were correctly collocated. Values observed for the magnitude of this drift typically ranged from 0.5 to 1.5 seconds, and the drift is thought to be caused by either the initial states of the buffers in the two instruments or in the overhead requirements of raw data processing. During post-processing, it was observed that once a correction value was found in the data, this value can be continually applied to subsequent collected data (since this lag is constant) or until the GPS unit is re-initialized.

Each data collection commenced with a calibration and synchronization procedure to determine the magnitude of the lag. The instrument was placed on a ferrite core calibration item (see Figure 8) with the DGPS streaming position data and the data acquisition on the GEM-3-E initiated. The instrument was moved forward a distance of 3 m and stopped. After a brief pause, the instrument was rolled back across the item to a distance 3 m behind the item and stopped. Finally, the sensor was moved back across the item and into the grid to begin the data collection run.

Data were collected for the 14 standardized test items in the test pit adjacent to the calibration lanes (see Figure 9) starting at the orange cones. The ½-in. (1.27-cm) plywood was placed over the hole to facilitate rolling the GEM-3-E over the items without having to completely fill in the hole before data collection. Ordnance items were positioned in the pit to give 0°, 45°, 90°, and 180° angles of orientation (see Figure 8). These data were used for algorithm training and discrimination processing.

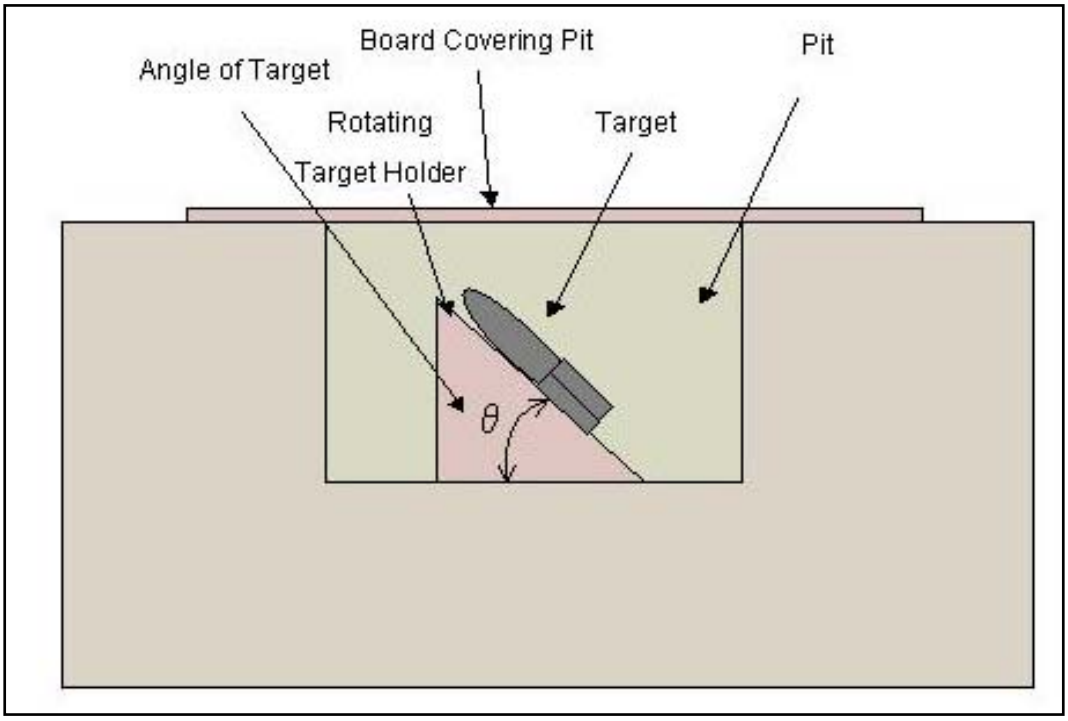

Figure 8. The calibration pit site configuration.

Figure 9. The calibration pit located next to calibration lanes.

Figure 10 shows an idealized data set from which the speed of the sensor and the sensor response are normalized and plotted on the same graph. The initial speed of the sensor is at zero and the sensor response is at a maximum. As the sensor is pushed past the item, the sensor response declines and the sensor speed rises. For this example, the change in speed from the sensor lags the decrease in sensor response. Measurement along the time axis will give the magnitude of the lag. The magnitude of the difference was used to shift the data so that the two streams are synchronized as illustrated in Figure 11.

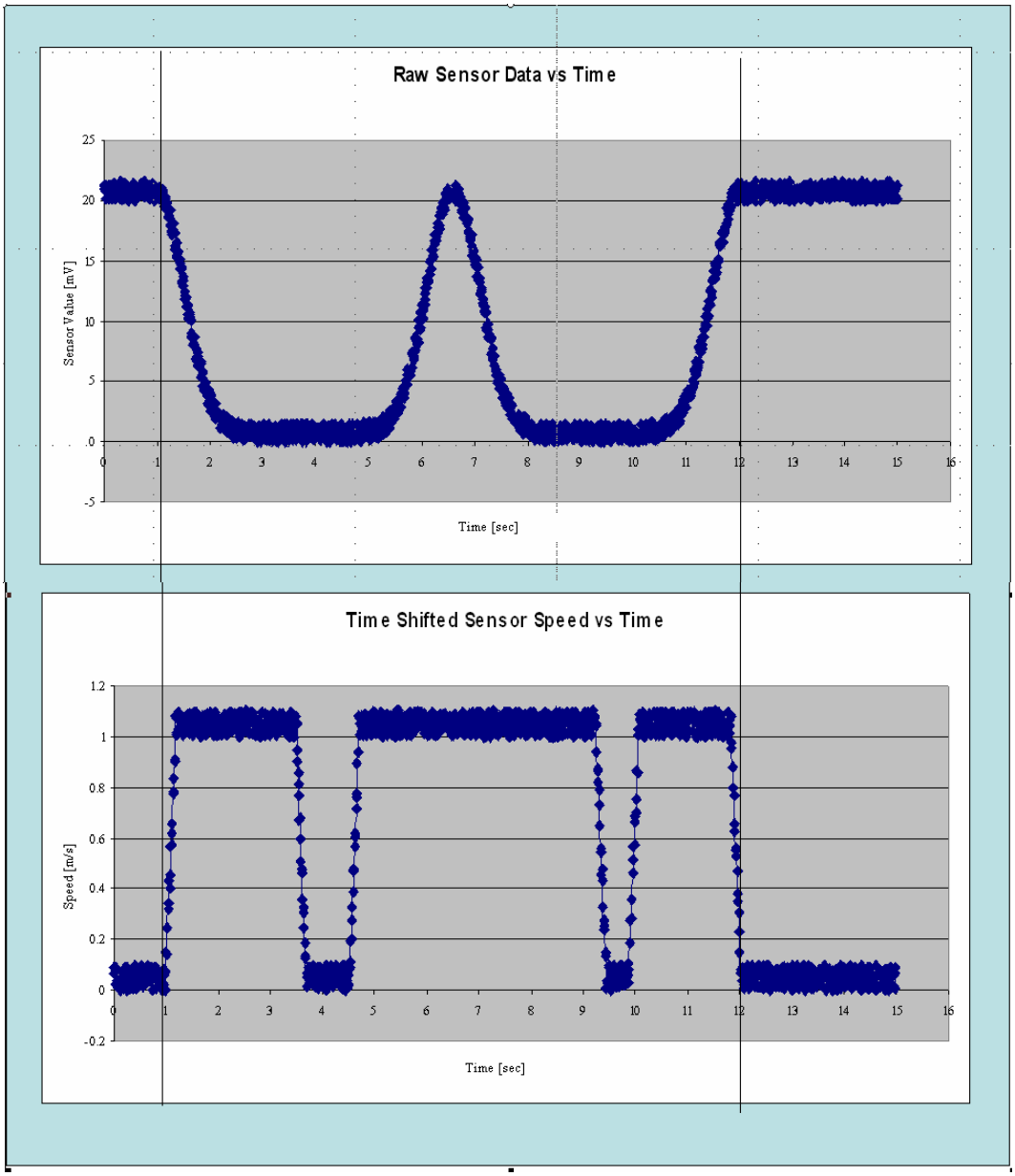

Figure 10. Idealized uncorrected GEM-3-E sensor speed and sensor response versus time.

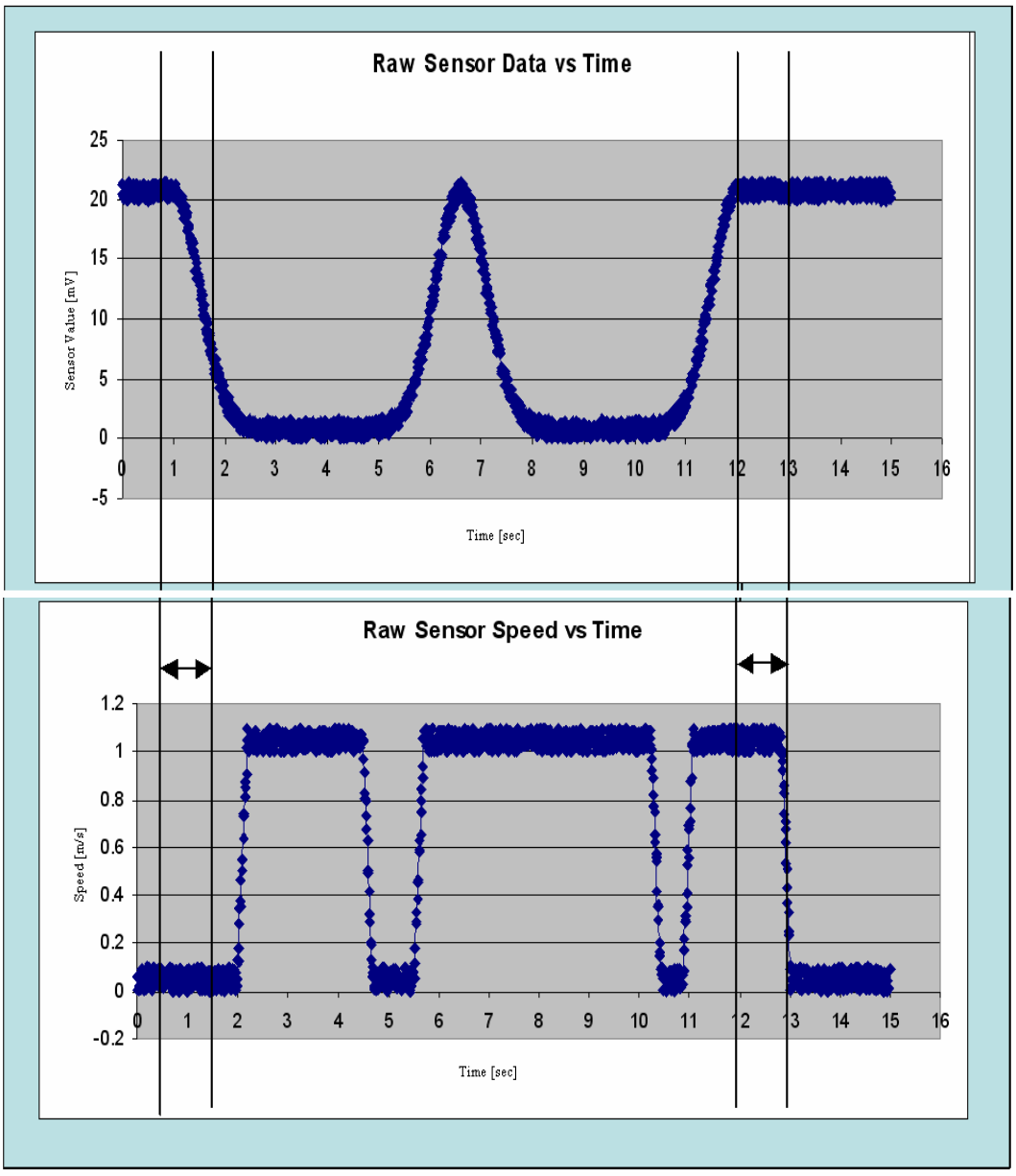

Figure 11. Idealized corrected GEM-3-E sensor speed and sensor response versus time.

Once the data are synchronized there is an additional check to insure the correctness of the drift. If the data are plotted on a surface map with x, y, the color of the point as sensor response, and with the drift corrected, then all three passes over of the item will appear as a single anomaly on the graph. An anomaly is a localized region within these data that exhibits a change in sensor response value greater than some baseline selected during post-processing. Data not synchronized will shift anomalies. An

example of raw data for the passes over an item can be seen in Figure 12. After the correction, the seemingly multiple targets converge into a larger single feature as shown in Figure 13. This represents a truer signature of the anomaly detection.

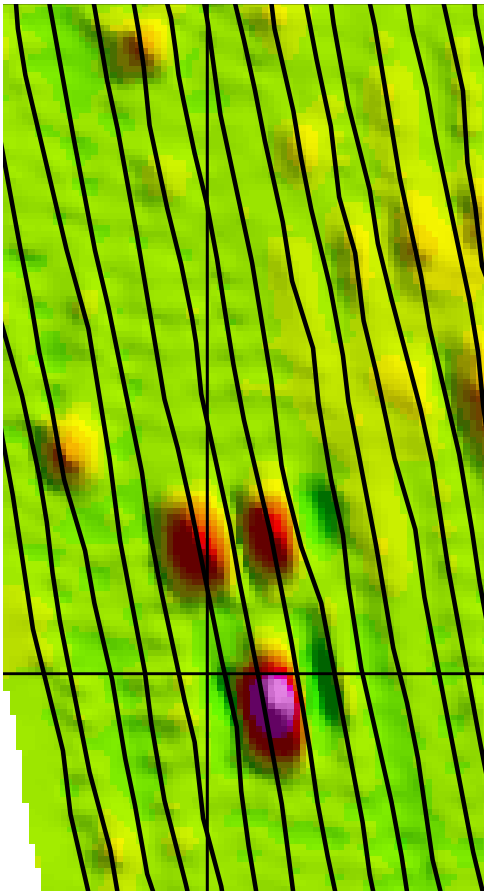

Figure 12. GEM-3-E raw data for the passes over an anomaly before lag correction.

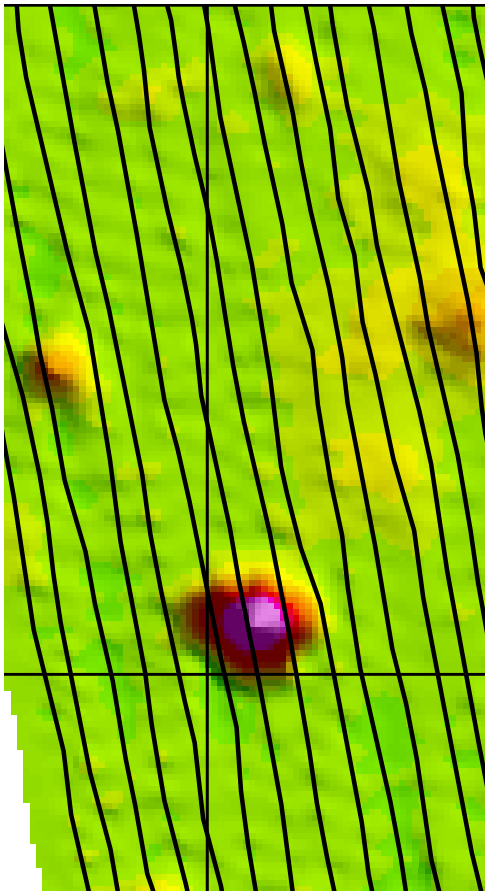

Figure 13. GEM-3-E data for the passes over an anomaly after lag correction.

Drift correction

A common problem encountered when collecting geophysical data is instrument drift (see Figure 14). The GEM-3-E signal level varies with time during data collection due to changes in temperature and battery power output. The Geosoft UX-Detect drift correction algorithm was applied to the data collected with the GEM-3-E system at YPG to compensate for this drift. This algorithm calculates the average for each user-specified block of data and subtracts the average from all points in the block. A percentage of points at the high and/or low end of the range of values are excluded from the calculation of the average so that the

presence of targets in the data block does not skew the average. Ideally, only background points will be included in the calculation of average; however, this can be difficult to achieve in areas densely populated with targets. Figure 14 shows a single channel of data for one survey line before and after drift correction. The uncorrected data, shown in red, have a significant downward drift, which is no longer present in the corrected data that are shown in green. Drift correction is performed on each data channel independently.

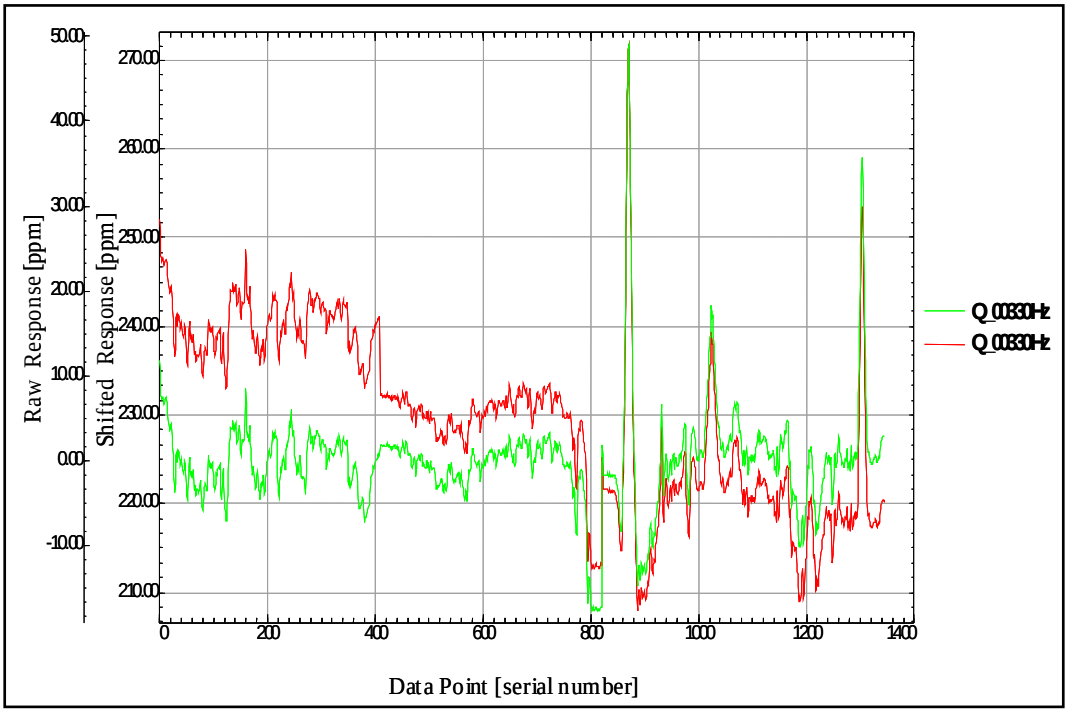

Figure 14. GEM-3-E (330 Hz) drift corrected (green) and uncorrected (red) signal levels.

5 Data Collection GEM-3-E

GEM-3-E system operation

Prior to the collection of each data acquisition grid, the GEM-3-E cart was positioned with the sensor head directly over the ferrite core. When data acquisition was initiated, the system was left over a ferrite core for 2 to 3 seconds to allow the system to "warm up." The cart was rolled backwards off the core then run back over the core twice. This gave a precise start and stop time so any time lag in the GPS could then be corrected.

The GEM-3-E was rolled into position for the next data acquisition lane. Once the GEM-3-E was positioned on the correct line, the operator started data collection and walked down the lane. At the end of every lane, the data acquisition was stopped and the lane number was advanced.

GEM-3-E data storage

There are two GEM-3-E data storage systems available. The data were either stored on the data acquisition module or on an iPAQ. The iPAQ was only used one day.

When the data were stored on the data acquisition module, they were downloaded to the computer using the WinGEM2K software via a serial port connection. The data acquisition module was powered on and the WinGEM2K software was initiated. From the tool bar, the download data were selected. The file was named and a download location was selected.

When the iPAQ was used to store data, a different procedure was used for download and director selection. The iPAQ was disconnected from the GEM-3-E and connected to the laptop by a USB connection. The ActiveSync program was activated and the files were downloaded to the laptop hard drive. These files were then copied to a new directory for further analysis.

GEM-3-E GPS sensor data integration

A GEM-3-E input port was used to facilitate the integration of GPS data. Care was taken to synchronize the data streams and to remove lag, which

was discussed in the post-processing QA/QC Procedures GPS Corrections section.

GEM-3-E coverage maps

The gridded coverage maps of the GEM-3-E are as follows: Figure 15 shows the line path covered by the GEM-3-E. Small gaps appeared in the 0.5-m coverage map, as shown in Figure 16, but disappeared with a grid cell resolution of 0.75 m (see Figure 17). This indicates that while there were a few departures from the nominal line spacing of 0.5 m, none of them were very large.

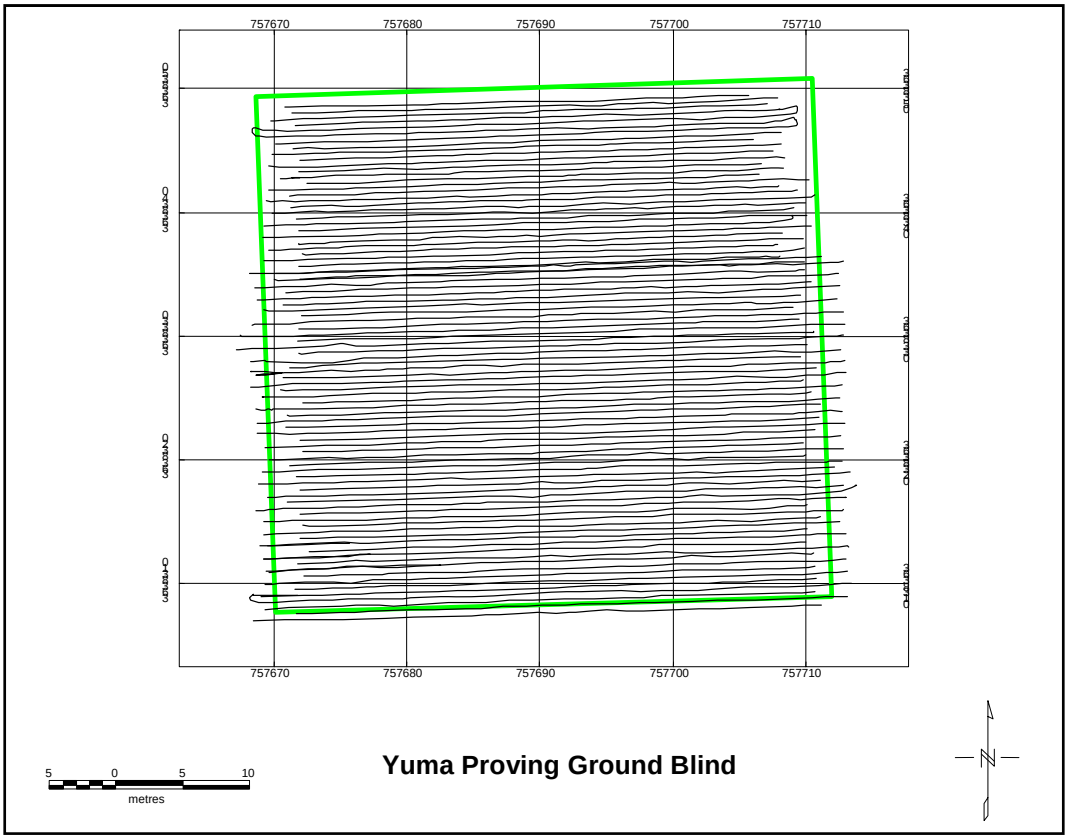

Figure 15. GEM-3-E site traverses.

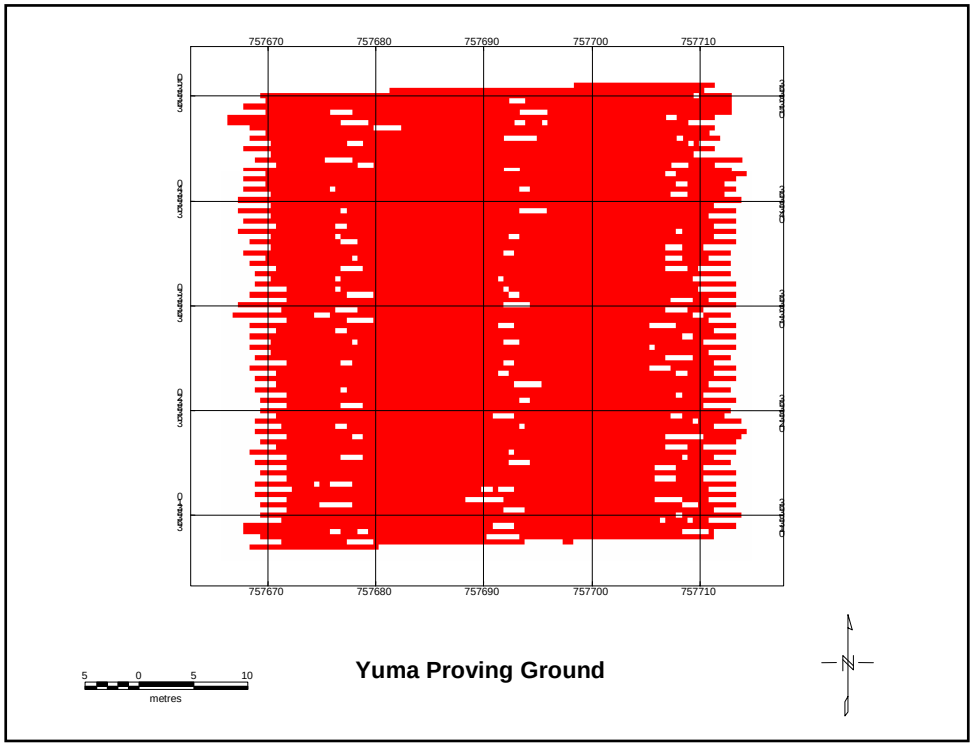

Figure 16. GEM-3-E coverage map using 0.5-m grid spacing.

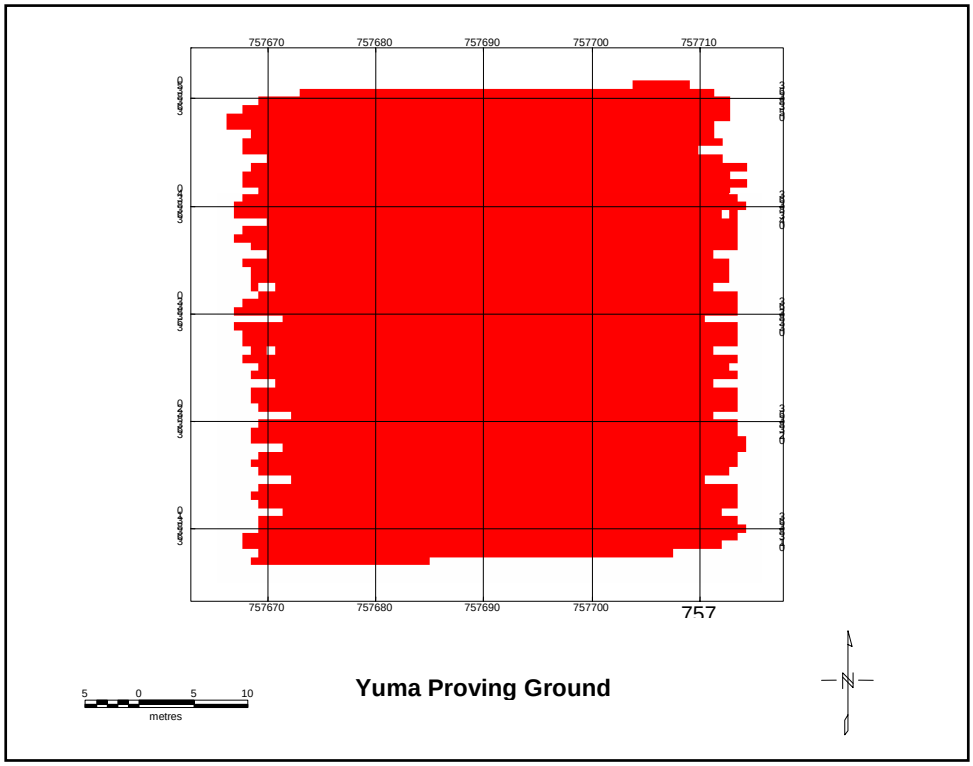

Figure 17. GEM-3-E coverage map using 0.75-m grid spacing.

6 System Evaluation GEM-3-E

Scoring of system

The scoring results obtained from the ATC for the GEM-3-E (USAEC 2005a, 2005b, 2005c, 2005d) are provided in Tables 2 to 5. The performance of the GEM-3-E was better at the Aberdeen Proving Ground (APG) test site (Bennett et al. 2006) with a probability of detection (P_d) of 0.60 for the response stage. This was due to a higher signal noise ratio (SNR) of the GEM-3-E system used at the APG test site. The systems used at the two sites were different instruments of the same model. The following variable definitions were obtained from the ATC website as follows (see Appendix D):

- P_{det}^{dsc} = (# of discrimination-stage detections)/(# of emplaced ordnance in the test site).
- P_{det}^{res} = (# of response-stage detections)/(# of emplaced ordnance in the test site).
- P_{fp}^{res} = (# of response-stage false positives)/(# of emplace clutter items).
- Emplaced Ordnance – An inert ordnance item buried by the government at a specified location in the test site.
- Emplaced Clutter – A clutter item (i.e., non-ordnance item) buried by the government at a specified location in the test site.
- Discrimination Stage – The ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly column, the DISCRIMINATION STAGE column contains the output of the algorithms applied in the discrimination-stage processing. This column is prioritized based on the confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that provides optimum system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).
- Response Stage – The ability of the demonstrator's system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. The RESPONSE STAGE provides the location and signal strength of all anomalies deemed sufficient to warrant

further investigation and /or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.

Results for the BTG are analyzed by size, depth, standard and nonstandard ordnance which are presented in Table 2. The standard column of Table 2 represents the targets which are the following ordnances: 20 mm, 40 mm, M42, BLU-26, BDU-28, 57 mm, MK118, 60 mm, 81 mm, M230, 105 mm, and 155 mm (see Figure 18). The nonstandard column is reporting on the other ordnances buried at YPG test site. Results by size and depth include both standard and nonstandard ordnance. The results by size show how well the ERDC team did at detecting/discriminating ordnance of a certain caliber range. The results are relative to the number of ordnances emplaced. Depth is measured from the closest point of anomaly to the ground surface.

The RESPONSE STAGE results are derived from the list of anomalies above the demonstrator-provided noise level threshold. The results for the DISCRIMINATION STAGE are derived from the demonstrator's recommended threshold for optimizing UXO field cleanup by minimizing false digs and maximizing ordnance recovery. The lower 90-percent confidence interval (CI) on probability of detection and probability of false positive was calculated assuming that the number of detections and false positives are binomially distributed random variables. All results in Table 2 have been rounded to protect site ground truth. However, lower confidence limits were calculated using actual results. The response stage noise level threshold was set to 50 ppm for the quadrature sum while the discrimination stage was thresholded with 70 ppm for the quadrature sum. In Table 2 through Table 5, the discrimination stage shows a slight decrease in the P_d value due to the different thresholds.

Figure 18. Standard inert ordnance targets.

Table 2. Enhanced GEM-3/pushcart - blind grid results (USAEC 2005a).

Metric	Overall	Standard	Non-standard	By Size			By Depth, m		
				Small	Medium	Large	<0.3	0.3-<1	>=1
RESPONSE STAGE									
P_d	0.45	0.45	0.50	0.30	0.50	0.80	0.50	0.50	0.00
P_d L90CI	0.38	0.34	0.35	0.20	0.37	0.58	0.40	0.35	0.00
P_{fp}	0.80						0.85	0.65	0.00
P_{fp} L90CI	0.74						0.79	0.50	
P_{ba}	0.05								
DISCRIMINATION STAGE									
P_d	0.45	0.40	0.50	0.25	0.50	0.80	0.45	0.50	0.00
P_d L90CI	0.35	0.30	0.35	0.15	0.37	0.58	0.36	035	0.00
P_{fp}	0.75						0.80	0.55	0.00
P_{fp} L90CI	0.68						0.72	0.43	
P_{ba}	0.00								

Table 3. Enhanced GEM-3/pushcart – open field results (USAEC 2005b).

Metric	Overall	Standard	Non-standard	By Size			By Depth, m		
				Small	Medium	Large	<0.3	0.3-<1	>=1
RESPONSE STAGE									
P_d	0.45	0.45	0.55	0.35	0.60	0.65	0.50	0.50	0.05
P_d L90CI	0.44	0.39	0.48	0.31	0.52	0.60	0.46	0.46	0.03
P_{fp}	0.50						0.55	0.50	0.00
P_{fp} L90CI	0.50						0.51	0.47	0.00
P_{ba}	0.15								
DISCRIMINATION STAGE									
P_d	0.45	0.40	0.50	0.30	0.55	0.65	0.45	0.50	0.05
P_d L90CI	0.41	0.37	0.44	0.27	0.50	0.57	0.43	0.44	0.03
P_{fp}	0.50						0.50	0.45	0.00
P_{fp} L90CI	0.47						0.48	0.42	0.00
P_{ba}	0.05								

Table 4. Enhanced GEM-3/pushcart – moguls results (USAEC 2005c).

Metric	Overall	Standard	Non-standard	By Size			By Depth, m		
				Small	Medium	Large	<0.3	0.3-<1	>=1
RESPONSE STAGE									
P_d	0.30	0.30	0.35	0.20	0.35	0.65	0.35	0.35	0.15
P_d L90CI	0.27	0.23	0.26	0.15	0.25	0.46	0.26	0.23	0.01
P_{fp}	0.35						0.35	0.25	0.00
P_{fp} L90CI	0.29						0.31	0.17	0.00
P_{ba}	0.05								
DISCRIMINATION STAGE									
P_d	0.30	0.25	0.35	0.15	0.35	0.55	0.30	0.30	0.15
P_d L90CI	0.23	0.18	0.24	0.11	0.25	0.35	0.22	0.18	0.01
P_{fp}	0.35						0.35	0.25	0.00
P_{fp} L90CI	0.28						0.30	0.15	0.00
P_{ba}	0.05								

Table 5. Enhanced GEM-3/pushcart – desert extreme results (USAEC 2005d).

Metric	Overall	Standard	Non-standard	By Size			By Depth, m		
				Small	Medium	Large	<0.3	0.3-<1	>=1
RESPONSE STAGE									
P_d	0.25	0.25	0.15	0.10	0.30	0.60	0.20	0.30	0.20
P_d L90CI	0.18	0.21	0.10	0.06	0.18	0.43	0.13	0.22	0.02
P_{fp}	0.40						0.40	0.40	0.00
P_{fp} L90CI	0.37						0.37	0.32	0.00
P_{ba}	0.00								
DISCRIMINATION STAGE									
P_d	0.20	0.20	0.15	0.05	0.25	0.55	0.15	0.25	0.00
P_d L90CI	0.15	0.16	0.08	0.03	0.16	0.38	0.11	0.18	0.00
P_{fp}	0.40						0.40	0.35	0.00
P_{fp} L90CI	0.34						0.35	0.25	0.00
P_{ba}	0.00								

Limitations of the GEM-3-E

There are physical limitations to the GEM-3-E affecting its ability to perform as a UXO Detection system. The most significant limitation of this system is the inability to detect targets below a depth of 1 m. This is indicated by a zero value for P_d in Tables 2 to 5 when targets were deeper than 1 m, which was the threshold selected by this study. The durability of some system components such as the nylon bolts holding the wheels to this cart could limit the use of this system for operational site characterization activities.

The 8-lb shot at the depth of 0.2 m was used to analysis the peak distance, in-phase, quadrature, and combined SNR for the enhanced GEM-3-E/pushcart (see Table 6).

Table 6. Analysis of 8-pound shot at depth = 0.2 ft

Target ID	Depth, ft	Orientation AZ/deg Inclination		GEM-3-E			
				Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
53	0.2			0.087464	31.86329	24.99054	31.02864
66	0.2			0.01456	31.51891	24.71825	30.70044
79	0.91			0.024698	30.06215	24.01624	29.438
92	0.2			0.04653	31.53488	25.13702	30.81681
97	0.2			0.120934	31.57845	24.44336	30.68479
104	0.2			0.039825	31.92801	24.79675	31.0329
127	0.2	0		3716446	13.38036	18.54165	19.18183
128	0.2	0		3716444	14.41425	17.26715	18.42095
129	0.2	0		3716442	10.49395	15.54625	16.2008
130	0.2	0		3716440	12.68228	17.30194	18.13758
131	0.2	0		3716438	10.7166	12.42445	14.07909
132	0.2	0		3716436	13.91148	13.28757	15.82933
133	0.2	0		3716434	12.16211	9.498167	12.87845
134	0.2	0		0.055543	30.50791	24.25529	29.82744
135	0.2	0		0.137179	29.95804	24.63073	29.54032
136	0.2	0		0.031623	31.35429	24.90461	30.62253
137	0.2	0		0.079812	30.04517	24.97686	29.71143
138	0.2	0		3716424	13.34349	13.87887	15.79162
139	0.2	0		0.122385	28.00838	24.14625	28.09939
140	0.2	0		0.022	26.70898	23.29003	26.98172
141	0.2	0		0.101597	28.89059	24.54164	28.79879
142	0.2	0		0.10538	29.56216	24.48269	29.22587
143	0.2	0		0.257029	29.28031	24.45758	29.02748
144	0.2	0		0.194487	28.80531	23.79073	28.48828
145	0.2	0		0.035228	30.27916	24.73482	29.79911
146	0.2	0		0.04669	31.34053	25.36079	30.73472
147	0.2	0		0.102956	30.22459	24.37669	29.65474
148	0.2	0		0.171919	28.79066	22.92465	28.22034
149	0.2	0		0.040311	28.88443	24.17345	28.66797
150	0.2	0		0.013928	27.4926	22.76691	27.27237
151	0.2	0		0.04826	29.0276	24.21302	28.78207
152	0.2	0		0.056321	29.03179	22.24398	28.21863
153	0.2	0		0.10412	29.10857	24.29503	28.85872
154	0.2	0		0.110725	29.37896	24.91848	29.25035
155	0.2	0		0.07267	27.47786	19.8246	26.47266
156	0.2	0		0.049729	31.12196	24.17616	30.27264
157	0.2	0		0.041049	31.05144	23.43314	30.05156

Target ID	Depth, ft	Orientation AZ/deg Inclination		GEM-3-E			
				Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
158	0.2	0		0.063325	29.61737	22.09354	28.63739
159	0.2	0		0.116932	27.08156	22.67856	26.97344
160	0.2	0		0.164469	30.05108	23.04822	29.18544
161	0.2	0		0.066068	29.78682	24.11576	29.26732
162	0.2	0		0.211967	26.41429	20.13042	25.72721
163	0.2	0		0.155242	27.84577	22.81244	27.5233
164	0.2	0		0.118186	28.82265	24.20454	28.63654
165	0.2	0		0.154984	30.5609	24.96163	30.06182
166	0.2	0		0.126874	30.45853	24.10934	29.75284
167	0.2	0		0.106301	30.63624	24.19476	29.91074
168	0.2	0		0.040311	31.06528	24.64359	30.34083
169	0.2	0		0.080156	31.01174	24.54525	30.27713
170	0.2	0		0.072062	31.39049	26.181	31.01825
171	0.2	0		0.049204	30.75433	22.9598	29.72172
172	0.2	0		0.301166	31.53956	25.20855	30.84045
173	0.2	0		0.211244	32.88047	25.66681	31.96812
174	0.2	0		0.232691	32.69676	26.16131	31.94477
175	0.2	0		0.127781	31.3816	24.94753	30.6537
176	0.2	0		0.075472	30.5903	24.0323	29.83373
177	0.2	0		0.244884	32.45668	25.80035	31.67358
178	0.2	0		0.110277	32.95354	26.42905	32.20314
179	0.2	0		0.19598	31.08532	24.73633	30.37979
180	0.2	0		0.217789	31.91833	24.7834	31.02254
181	0.2	0		0.129449	31.85146	25.90419	31.25327
182	0.2	0		0.068264	32.48545	26.3123	31.82576

7 Conclusions

Conclusions are as follows:

1. The ERDC team experienced down time due to problems with the GEM-3-E pushcart. The wheel became dislodged repeatedly from the pushcart during operation. Additional manpower was used to assist the mobility of the cart. Ropes were attached to the side of the pushcart to take the weight off of the wheel and allow site survey activities to continue even in very difficult terrain. The fragility of the system could limit the use of this system for operational site characterization activities.

2. Four personnel were required to operate the GEM-3-E due to the axle failures. With improvements to the functionality of the pushcart, three personnel should be able to operate the GEM-3-E pushcart system.

3. The most significant limitation of the GEM-3-E was the inability to detect targets below a depth of 1 m. This is indicated by a zero value for P_d, in Tables 3 and 4, when the targets were located deeper than 1 m, which was the threshold selected by this study.

4. With respect to the calibration lane data, the in-phase signal showed an improvement by the GEM-3-E. However, the quadrature did not show any clear improvement in this enhanced model. These results may be due to the GEM-3-E calibration favoring the in-phase. The magnitude of the in-phase response for the GEM-3-E was three times greater than the magnitude of the quadrature. The ferrite core calibration was performed and the in-phase response was level, indicating that the in-phase was properly calibrated for this system. However, the q-coil calibration was not performed. This calibration would align the quadrature calibration with respect to the in-phase. When extreme level imbalances are detected, the systems must be returned to the manufacturer for q-coil calibration and level balancing.

8 Recommendations

Recommendations are as follows:

1. During future use of the GEM-3-E, the assumption should not be made that, if the in-phase was calibrated, the quadrature was balanced with respect to the in-phase.

2. The amplitude comparison of the calibration lane data should be made to compensate for the poorly balanced GEM-3-E.

3. The pushcart should be ruggedized for field survey applications.

4. The GEM-3 system should be used for shallow depth (<1 m) UXO detection and discrimination applications.

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Appendix A: Dig List

Target ID	Description	Depth	Orientation az/deg Inclination		GEM-3-E			
					Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
1	12 gauge 30-cm loop	0.25	n/a	0	0.045398	46.04636	35.30383	44.5587
2	12 gauge 30-cm loop	0.25	0 az	90	0.30566	25.98845	20.31314	25.48962
3	12 gauge 15-cm loop	0.25	n/a	0	0.267606	29.71297	19.62567	28.30872
4	12 gauge 15-cm loop	0.25	0 az	90	0.243288	17.2155	7.825406	15.91559
5	16 gauge 30-cm loop	0.25	n/a	0	0.173566	43.00444	34.43607	41.82364
6	16 gauge 30-cm loop	0.25	0 az	90	0.210281	25.23585	17.97142	24.31616
7	16 gauge 15-cm loop	0.25	n/a	0	0.028653	27.37665	18.04112	26.07256
8	16 gauge 15-cm loop	0.25	0 az	90	0.307002	10.81603	9.568593	12.26114
9	12-lb shot	0.5	n/a	0	0.145121	11.84672	14.1521	15.36613
10	12-lb shot	1	n/a	0	0.155602	1.284211	8.26164	8.791267
11	12-lb shot	1.5	n/a	0	0.185777	7.392535	5.753826	9.069432
12	12-lb shot	2	n/a	0	0.188298	8.298423	9.998932	11.89752
13	18 gauge 30-cm loop	0.25	n/a	0	0.07433	41.13254	32.75551	39.98567
14	18 gauge 30-cm loop	0.25	0 az	90	0.334631	21.02256	19.35848	22.10758
15	18 gauge 15-cm loop	0.25	n/a	0	0.264518	26.20331	16.6502	24.87222
16	18 gauge 15-cm loop	0.25	0 az	90	0.054424	13.07343	7.19131	12.57323
17	20 gauge 30-cm loop	0.25	n/a	0	0.210155	38.57211	32.41523	37.91659
18	20 gauge 30-cm loop	0.25	0 az	90	0.314033	19.6117	16.17238	19.87133
19	20 gauge 15-cm loop	0.25	n/a	0	0.023409	23.69284	16.31521	22.74466
20	20 gauge 15-cm loop	0.25	0 az	90	0.242244	6.977257	10.09289	11.43448
21	20-mm M55	0.1	0 az	45	0.219021	8.084613	8.58289	10.61786
22	20-mm M55	0.1	0 az	-45	0.129124	9.012208	8.06082	10.79043
23	20-mm M55	0.1	n/a	90	0.328694	8.210545	7.472871	10.38011
24	20-mm M55	0.1	n/a	-90	0.224129	7.467432	8.502005	10.39216
25	20-mm M55	0.2	0 az	0	0.042154	5.947251	9.244053	10.41961
26	20-mm M55	0.2	180az	0	0.240002	1.044412	8.666164	9.039016
27	8-lb shot	0.2			0.102825	31.91126	25.40819	31.16716
28	40-mm MK II	0.15	0 az	45	0.210152	19.82306	20.28555	22.10005
29	40-mm MK II	0.15	0 az	-45	0.103586	19.2748	18.27415	20.68744
30	40-mm MK II	0.15	n/a	90	0.044553	22.40968	23.04314	24.79004
31	40-mm MK II	0.15	n/a	-90	0.168048	16.18526	17.35594	18.92387
32	40-mm MK II	0.3	0 az	0	0.075313	9.906054	6.695668	10.25782
33	40-mm MK II	0.3	180az	0	0.057871	11.54662	9.57904	12.48743
34	40-mm M385	0.1	0 az	45	0.033734	20.93221	11.98803	19.72518

Target ID	Description	Depth	Orientation az/deg Inclination		GEM-3-E			
					Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
35	40-mm M385	0.1	0 az	-45	0.034059	19.95184	14.12924	19.68177
36	40-mm M385	0.1	n/a	90	0.277872	18.81413	5.905902	17.14277
37	40-mm M385	0.1	n/a	-90	0.043658	18.48009	3.358724	16.69955
38	40-mm M385	0.2	0 az	0	0.267152	16.49819	4.450576	15.05567
39	40-mm M385	0.2	180az	0	0.074243	11.88517	9.233161	12.51536
40	8-lb shot	0.2			0.110887	32.08488	25.13296	31.23101
41	M42	0.15	0 az	45	0.112872	15.95128	14.09265	16.92564
42	M42	0.15	0 az	-45	0.082006	17.48002	11.79465	16.97414
43	M42	0.15	n/a	90	0.141834	17.87633	15.66757	18.67429
44	M42	0.15	n/a	-90	0.184201	16.94904	14.69536	17.7427
45	M42	0.35	0 az	0	0.098494	5.381633	8.300152	9.78852
46	M42	0.35	180az	0	0.143126	6.505894	5.691042	8.203534
47	BLU-26	0.1	n/a	0	0.074411	21.92956	19.02954	22.40914
48	BLU-26	0.1	n/a	0	0.073498	20.75514	18.56464	21.59617
49	BLU-26	0.1	n/a	0	0.331183	20.59031	17.68289	21.11658
50	BLU-26	0.1	n/a	0	0.15769	20.44115	17.54554	20.94536
51	BLU-26	0.2	n/a	0	0.338095	14.38264	9.966319	14.30848
52	BLU-26	0.2	n/a	0	0.227035	12.67858	12.35277	14.47585
53	8-lb shot	0.2			0.087464	31.86329	24.99054	31.02864
54	BDU-28	0.1	0 az	45	0.222092	12.37517	12.93892	14.71023
55	BDU-28	0.1	0 az	-45	0.124326	24.64688	18.91107	24.1146
56	BDU-28	0.1	n/a	90	0.124064	15.96304	11.51392	15.88335
57	BDU-28	0.1	n/a	-90	0.130771	27.43487	17.7066	26.07578
58	BDU-28	0.2	0 az	0	0.02377	17.87125	14.47749	18.21448
59	BDU-28	0.2	180az	0	0.079057	19.29123	9.920792	17.99131
60	57-mm M86	0.4	0 az	45	0.032757	11.07676	14.06922	15.12025
61	57-mm M86	0.4	0 az	-45	0.10959	8.537169	6.916072	9.638531
62	57-mm M86	0.4	n/a	90	0.27927	9.562678	14.85687	15.43515
63	57-mm M86	0.4	n/a	-90	0.318157	10.15905	10.54775	12.66133
64	57-mm M86	0.91	0 az	0	0.252343	9.375226	10.43424	12.27657
65	57-mm M86	0.91	180az	0	0.054708	8.8068	-2.05006	7.363422
66	8-lb shot	0.2			0.01456	31.51891	24.71825	30.70044
67	MK 118 Rockeye	0.3	0 az	45	0.339796	7.334621	-4.38743	6.061586
68	MK 118 Rockeye	0.3	0 az	-45	0.153056	12.70916	8.772865	12.8205
69	MK 118 Rockeye	0.3	n/a	90	0.212984	-0.65331	9.468533	9.588865
70	MK 118 Rockeye	0.3	n/a	-90	0.299862	7.175468	7.181343	9.309465
71	MK 118 Rockeye	0.6	0 az	0	0.308058	2.69895	2.221935	4.788337
72	MK 118 Rockeye	0.6	180az	0	0.150083	5.318536	-0.15237	5.54576

Target ID	Description	Depth	Orientation az/deg Inclination		GEM-3-E			
					Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
73	60-mm M49A3	0.4	0 az	45	0.05021	15.31714	11.85163	15.57462
74	60-mm M49A3	0.4	0 az	-45	0.201122	8.721837	7.600725	10.32679
75	60-mm M49A3	0.4	n/a	90	0.270326	9.043808	14.49703	15.11909
76	60-mm M49A3	0.4	n/a	-90	0.296709	5.577736	8.867345	10.02102
77	60-mm M49A3	0.4	0 az	0	0.139445	7.811353	9.453322	11.23003
78	60-mm M49A3	0.91	180az	0	0.062177	11.81996	12.41007	14.22995
79	8-lb shot	0.91			0.024698	30.06215	24.01624	29.438
80	81-mm M374	0.5	0 az	45	0.151476	7.568478	8.768149	10.35434
81	81-mm M374	0.5	0 az	-45	0.122201	14.31739	13.53407	15.85759
82	81-mm M374	0.5	n/a	90	0.300148	5.119194	6.461851	8.378792
83	81-mm M374	0.5	n/a	-90	0.213354	11.02848	10.11056	12.58131
84	81-mm M374	1.5	0 az	0	0.083235	0.672626	7.373792	8.020512
85	81-mm M374	1.5	180az	0	0.180278	10.43011	5.137051	10.49624
86	2.75 M230	0.5	0 az	45	0.080062	18.93994	17.44359	20.1231
87	2.75 M230	0.5	0 az	-45	0.1822	13.1616	13.80518	15.70239
88	2.75 M230	0.5	n/a	90	0.193342	18.71731	19.35539	21.1016
89	2.75 M230	0.5	n/a	-90	0.256164	16.61077	12.28417	16.55109
90	2.75 M230	1.2	0 az	0	0.172351	7.882354	2.095017	7.770577
91	2.75 M230	1.2	180az	0	0.243731	5.762016	3.986436	7.332817
92	8-lb shot	0.2			0.04653	31.53488	25.13702	30.81681
93	60-mm M49A3/No Clutter	0.25	0 az	0	0.174771	21.90079	18.05243	22.00552
94	60-mm M49A3/Low Clutter	0.25	0 az	0	0.158493	32.83856	26.63522	32.22475
95	60-mm M49A3/Medium Clutter	0.25	0 az	0	0.183992	36.55491	28.55443	35.4946
96	60-mm M49A3/High Clutter	0.25	0 az	0	0.102883	38.4628	30.93983	37.4892
97	8-lb shot	0.2			0.120934	31.57845	24.44336	30.68479
98	M75	0.15	0 az		0.08956	23.13705	18.65952	23.00562
99	M75	0.15	0 az		0.034015	23.72822	19.26538	23.59466
100	M75	0.15	n/a		0.169499	21.57682	16.33662	21.1875
101	M75	0.15	n/a		0.109385	23.92078	20.57377	24.21439
102	M75	0.3	0 az		0.157918	15.29115	11.01641	15.2458
103	M75	0.3	180 az		0.040497	13.56248	14.58601	16.30273
104	8-lb shot	0.2			0.039825	31.92801	24.79675	31.0329
105	30-cm steel plate	0.5	n/a	0	0.037014	29.52633	23.50995	28.96162
106	30-cm steel plate	1	n/a	0	0.288368	11.76831	9.058465	12.53851
107	60-cm steel plate	0.5	n/a	0	0.1236	51.16052	38.10414	49.46719
108	60-cm steel plate	1	n/a	0	0.121758	28.26969	16.86764	26.71586
109	105-mm M456 heat	0.4	0 az	45	0.105513	20.77578	12.11541	19.75219
110	105-mm M456 heat	0.4	0 az	-45	0.251311	20.01344	15.94048	20.06212

Target ID	Description	Depth	Orientation az/deg Inclination		GEM-3-E			
					Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
111	105-mm M456 heat	0.4	n/a	90	0.247342	14.6361	7.157489	13.75047
112	105-mm M456 heat	0.4	n/a	-90	0.090139	18.61562	17.16469	19.81795
113	105-mm M456 heat	0.8	0 az	0	0.116765	6.768506	10.08564	11.06352
114	105-mm M456 heat	0.8	180az	0	0.173289	9.391621	12.23677	13.37074
115	105-mm M60	0.4	0 az	45	0.24233	24.56468	20.54948	24.60639
116	105-mm M60	0.4	0 az	-45	0.120017	22.82583	22.33305	24.53661
117	105-mm M60	0.4	n/a	90	0.154842	20.63184	19.23866	21.87461
118	105-mm M60	0.4	n/a	-90	0.126779	21.57689	21.90381	23.76039
119	105-mm M60	0.8	0 az	0	0.144184	8.032037	10.37852	11.59194
120	105-mm M60	0.8	180az	0	0.100005	9.644265	8.043313	10.78427
121	155-mm M483A1	0.75	0 az	45	0.254637	15.79475	12.32389	16.26553
122	155-mm M483A1	0.75	0 az	-45	0.208543	13.78841	14.27637	16.08517
123	155-mm M483A1	0.75	n/a	90	0.127624	20.89539	6.286008	19.12306
124	155-mm M483A1	0.75	n/a	-90	0.324692	8.330532	5.651388	9.201432
125	155-mm M483A1	1.5	0 az	0	0.255314	6.996879	8.929585	10.50084
126	155-mm M483A1	1.5	180az	0	0.207562	9.577828	4.395556	9.86879
127	8-lb shot	0.2	0		3716446	13.38036	18.54165	19.18183
128	8-lb shot	0.2	0		3716444	14.41425	17.26715	18.42095
129	8-lb shot	0.2	0		3716442	10.49395	15.54625	16.2008
130	8-lb shot	0.2	0		3716440	12.68228	17.30194	18.13758
131	8-lb shot	0.2	0		3716438	10.7166	12.42445	14.07909
132	8-lb shot	0.2	0		3716436	13.91148	13.28757	15.82933
133	8-lb shot	0.2	0		3716434	12.16211	9.498167	12.87845
134	8-lb shot	0.2	0		0.055543	30.50791	24.25529	29.82744
135	8-lb shot	0.2	0		0.137179	29.95804	24.63073	29.54032
136	8-lb shot	0.2	0		0.031623	31.35429	24.90461	30.62253
137	8-lb shot	0.2	0		0.079812	30.04517	24.97686	29.71143
138	8-lb shot	0.2	0		3716424	13.34349	13.87887	15.79162
139	8-lb shot	0.2	0		0.122385	28.00838	24.14625	28.09939
140	8-lb shot	0.2	0		0.022	26.70898	23.29003	26.98172
141	8-lb shot	0.2	0		0.101597	28.89059	24.54164	28.79879
142	8-lb shot	0.2	0		0.10538	29.56216	24.48269	29.22587
143	8-lb shot	0.2	0		0.257029	29.28031	24.45758	29.02748
144	8-lb shot	0.2	0		0.194487	28.80531	23.79073	28.48828
145	8-lb shot	0.2	0		0.035228	30.27916	24.73482	29.79911
146	8-lb shot	0.2	0		0.04669	31.34053	25.36079	30.73472
147	8-lb shot	0.2	0		0.102956	30.22459	24.37669	29.65474
148	8-lb shot	0.2	0		0.171919	28.79066	22.92465	28.22034

Target ID	Description	Depth	Orientation az/deg Inclination		GEM-3-E			
					Peak Dist from UXO	In-phase Sum SNR	Quadrature Sum SNR	Comb SNR
149	8-lb shot	0.2	0		0.040311	28.88443	24.17345	28.66797
150	8-lb shot	0.2	0		0.013928	27.4926	22.76691	27.27237
151	8-lb shot	0.2	0		0.04826	29.0276	24.21302	28.78207
152	8-lb shot	0.2	0		0.056321	29.03179	22.24398	28.21863
153	8-lb shot	0.2	0		0.10412	29.10857	24.29503	28.85872
154	8-lb shot	0.2	0		0.110725	29.37896	24.91848	29.25035
155	8-lb shot	0.2	0		0.07267	27.47786	19.8246	26.47266
156	8-lb shot	0.2	0		0.049729	31.12196	24.17616	30.27264
157	8-lb shot	0.2	0		0.041049	31.05144	23.43314	30.05156
158	8-lb shot	0.2	0		0.063325	29.61737	22.09354	28.63739
159	8-lb shot	0.2	0		0.116932	27.08156	22.67856	26.97344
160	8-lb shot	0.2	0		0.164469	30.05108	23.04822	29.18544
161	8-lb shot	0.2	0		0.066068	29.78682	24.11576	29.26732
162	8-lb shot	0.2	0		0.211967	26.41429	20.13042	25.72721
163	8-lb shot	0.2	0		0.155242	27.84577	22.81244	27.5233
164	8-lb shot	0.2	0		0.118186	28.82265	24.20454	28.63654
165	8-lb shot	0.2	0		0.154984	30.5609	24.96163	30.06182
166	8-lb shot	0.2	0		0.126874	30.45853	24.10934	29.75284
167	8-lb shot	0.2	0		0.106301	30.63624	24.19476	29.91074
168	8-lb shot	0.2	0		0.040311	31.06528	24.64359	30.34083
169	8-lb shot	0.2	0		0.080156	31.01174	24.54525	30.27713
170	8-lb shot	0.2	0		0.072062	31.39049	26.181	31.01825
171	8-lb shot	0.2	0		0.049204	30.75433	22.9598	29.72172
172	8-lb shot	0.2	0		0.301166	31.53956	25.20855	30.84045
173	8-lb shot	0.2	0		0.211244	32.88047	25.66681	31.96812
174	8-lb shot	0.2	0		0.232691	32.69676	26.16131	31.94477
175	8-lb shot	0.2	0		0.127781	31.3816	24.94753	30.6537
176	8-lb shot	0.2	0		0.075472	30.5903	24.0323	29.83373
177	8-lb shot	0.2	0		0.244884	32.45668	25.80035	31.67358
178	8-lb shot	0.2	0		0.110277	32.95354	26.42905	32.20314
179	8-lb shot	0.2	0		0.19598	31.08532	24.73633	30.37979
180	8-lb shot	0.2	0		0.217789	31.91833	24.7834	31.02254
181	8-lb shot	0.2	0		0.129449	31.85146	25.90419	31.25327
182	8-lb shot	0.2	0		0.068264	32.48545	26.3123	31.82576

Appendix B: Activity Log

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030505	1015	1600	CALIBRATION LANES	1015	1045	0:00	30	30	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	4
20030505	1015	1600	CALIBRATION LANES	1015	1045	0:00	30	30	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	
20030505	1015	1600	CALIBRATION LANES	1045	1100	0	15	15	3	BREAK/LUNCH	LUNCH	NA	NA	HOT	DRY	4
20030505	1015	1600	CALIBRATION LANES	1100	1530	4	30	270	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	4
20030505	1015	1600	CALIBRATION LANES	1530	1600	0	30	30	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	4
20030506	730	1535	CALIBRATION LANES	730	815	0	45	45	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	815	915	1	0	60	2	COLLECTING DATA	RUNNING CAL LANE, BI DIRECTION, NORTH/SOUTH	NA	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	915	1030	1	15	75	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	1030	1120	0	50	50	2	COLLECTING DATA	RUNNING CAL LANE BI DIRECTION EAST/WEST	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	1120	1140	1	10	70	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	NA	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	1140	1210	0	30	30	3	BREAK/LUNCH	LUNCH	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION LANES	1210	1240	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	NA	NA	HOT	DRY	5
20030506	730	1535	BLIND TEST GRID	1240	1355	1	15	75	2	COLLECTING DATA	RUNNING BTG, BIDIRECTION EAST/WEST	GPS	NA	HOT	DRY	5
20030506	730	1535	BLIND TEST GRID	1355	1430	0	35	35	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION PIT	1430	1450	0	20	20	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION PIT	1450	1515	0	25	25	2	COLLECTING DATA	COLLECT DATA OVER PIT	GPS	NA	HOT	DRY	5

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030506	730	1535	CALIBRATION PIT	1515	1520	0	5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT BATTERY	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION PIT	1520	1525	0	5	5	2	COLLECTING DATA	COLLECT DATA OVER PIT	GPS	NA	HOT	DRY	5
20030506	730	1535	CALIBRATION PIT	1525	1535	0	10	10	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	5
20030507	715	1600	OPEN RANGE	715	855	1	40	100	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	855	1035	1	40	100	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID A2, BIDIRECTIONAL E/W	GPS	NA	COOL/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1035	1115	0	40	40	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1115	1125	0	10	10	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1125	1300	1	35	95	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID A3, BIDIRECTIONAL E/W	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1300	1330	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1330	1350	0	20	20	3	BREAK/LUNCH	BREAK	NA	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1350	1400	0	10	10	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1400	1530	1	30	90	2	COLLECTING DATA	RUNNING OPEN RANGE GRID G2, BIDIRECTIONAL E/W	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1530	1550	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT/WINDY	DRY	4
20030507	715	1600	OPEN RANGE	1550	1600	0	10	10	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT/WINDY	DRY	4
20030508	700	1600	OPEN RANGE	700	745	0	45	45	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL/WINDY	DRY	5
20030508	700	1600	OPEN RANGE	745	950	2	5	125	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID G3,G4, BIDIRECTIONAL E/W	GPS	NA	COOL/WINDY	DRY	5
20030508	700	1600	OPEN RANGE	950	1020	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL/WINDY	DRY	5

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030508	700	1600	BLIND TEST GRID	1020	1130	1	10	70	2	COLLECTING DATA	RUNNING BTG BIDIRECTIONAL NORTH/ SOUTH	GPS	NA	HOT/WINDY	DRY	5
20030508	700	1600	BLIND TEST GRID	1130	1145	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT/WINDY	DRY	5
20030508	700	1600	BLIND TEST GRID	1145	1215	0	30	30	3	BREAK/LUNCH	LUNCH	GPS	NA	HOT/WINDY	DRY	5
20030508	700	1600	OPEN RANGE	1215	1300	0	45	45	1	SET-UP/ MOBILIZATION	LAYOUT LANES WITH ROPE	NA	NA	HOT/WINDY	DRY	5
20030508	700	1600	CALIBRATION PIT	1300	1440	1	40	100	2	COLLECTING DATA	COLLECT DATA OVER PIT	GPS	NA	HOT/WINDY	DRY	5
20030508	700	1600	CALIBRATION PIT	1440	1500	0	20	20	3	BREAK/LUNCH	BREAK	NA	NA	HOT/WINDY	DRY	5
20030508	700	1600	OPEN RANGE	1500	1550	0	50	50	1	SET-UP/ MOBILIZATION	LAYOUT LANES WITH ROPE	NA	NA	HOT/WINDY	DRY	5
20030508	700	1600	OPEN RANGE	1550	1600	0	10	10	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	645	720	0	35	35	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL	DRY	4
20030509	645	1545	OPEN RANGE	720	845	1	25	85	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	COOL/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	845	905	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	905	1030	1	25	85	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	COOL/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	1030	1100	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	1100	1130	0	30	30	3	BREAK/LUNCH	LUNCH	NA	NA	COOL/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	1130	1250	1	20	80	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT/WINDY	DRY	4
20030509	645	1545	OPEN RANGE	1250	1300	0	10	10	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT PROCESSOR UNIT	GPS	NA	HOT/WINDY	DRY	4

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030509	645	1545	OPEN RANGE	1300	1330	0	30	30	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	1330	1430	1	0	60	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	1430	1445	0	15	15	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	1445	1500	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT BATTERY	GPS	NA	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	1500	1520	0	20	20	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID F2,F3,F4,F5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT/WINDY	DRY	5
20030509	645	1545	OPEN RANGE	1520	1540	0	20	20	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT/WINDY	DRY	5
20030510	630	1400	OPEN RANGE	630	700	0	30	30	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL	DRY	5
20030510	630	1400	OPEN RANGE	700	826	1	26	86	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID E2,E3,E4,E5 BIDIRECTIONAL E/W	GPS	LINEAR	COOL	DRY	5
20030510	630	1400	OPEN RANGE	826	828	0	2	2	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	SWAPPED OUT FIELD COMPUTER	GPS	LINEAR	COOL	DRY	5
20030510	630	1400	OPEN RANGE	828	1015	1	47	107	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID E2,E3,E4,E5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030510	630	1400	OPEN RANGE	1015	1040	0	25	25	3	BREAK/LUNCH	LUNCH	NA	NA	HOT	DRY	5
20030510	630	1400	OPEN RANGE	1040	1100	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030510	630	1400	OPEN RANGE	1100	1243	1	43	103	2	COLLECTING DATA	RUNNING OPENRANGE, GRID E2,E3,E4,E5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030510	630	1400	OPEN RANGE	1243	1246	0	3	3	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT PROCESSOR UNIT	GPS	NA	HOT	DRY	4

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030510	630	1400	OPEN RANGE	1246	1340	0	54	54	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID E2,E3,E4,E5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030510	630	1400	OPEN RANGE	1340	1400	0	20	20	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	GPS	NA	HOT	DRY	4
20030512	700	1330	OPEN RANGE	700	721	0	21	21	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	GPS	NA	HOT	DRY	5
20030512	700	1330	OPEN RANGE	721	725	0	4	4	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	5
20030512	700	1330	OPEN RANGE	725	825	1	0	60	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID E2,E3,E4,E5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030512	700	1330	OPEN RANGE	825	935	0	50	50	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030512	700	1330	OPEN RANGE	935	1025	0	50	50	2	COLLECTING DATA	RUNNING OPEN RANGE, GRID A4,A5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030512	700	1330	OPEN RANGE	1025	1030	0	5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030512	700	1330	OPEN RANGE	1030	1325	2	55	175	4	DOWNTIME DUE TO EQUIP FAILURE	WHEEL AXLE BROKE	NA	NA	HOT	DRY	5
20030512	700	1330	OPEN RANGE	1325	1330	0	5	5	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	5
20030513	1130	1600	OPEN RANGE	1130	1215	0	45	45	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	GPS	NA	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1215	1300	0	45	45	2	COLLECTING DATA	RUNNING OPEN RANGE, A4,A5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1300	1320	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1320	1430	1	10	70	2	COLLECTING DATA	RUNNING OPEN RANGE, A4,A5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1430	1447	0	17	17	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	4

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20030513	1130	1600	OPEN RANGE	1447	1535	0	48	48	2	COLLECTING DATA	RUNNING OPEN RANGE, A4,A5 BIDIRECTIONAL E/W	NA	LINEAR	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1535	1545	0	10	10	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030513	1130	1600	OPEN RANGE	1545	1600	0	15	15	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	4
20030514	630	1600	OPEN RANGE	630	735	1	5	65	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	735	739	0	4	4	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	LINEAR	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	739	850	1	11	71	2	COLLECTING DATA	RUNNING OPEN RANGE, A4,A5 BIDIRECTIONAL E/W	GPS	LINEAR	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	850	920	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	920	1020	1	0	60	2	COLLECTING DATA	RUNNING OPEN RANGE, D4,D5 BIDIRECTIONAL E/W	GPS	LINEAR	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1020	1035	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1035	1130	0	55	55	3	BREAK/LUNCH	LUNCH	NA	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1130	1325	1	55	115	2	COLLECTING DATA	RUNNING OPEN RANGE, D4,D5 BIDIRECTIONAL E/W	GPS	LINEAR	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1325	1400	0	35	35	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1400	1430	0	30	30	3	BREAK/LUNCH	BREAK	NA	NA	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1430	1530	2	0	120	2	COLLECTING DATA	RUNNING OPEN RANGE, D4,D5 BIDIRECTIONAL E/W	GPS	LINEAR	WARM	HUMID	5
20030514	630	1600	OPEN RANGE	1530	1600	0	30	30	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	WARM	HUMID	5
20030515	645	1600	OPEN RANGE	645	710	0	25	25	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL	DRY	5

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030515	645	1600	OPEN RANGE	710	735	0	25	25	2	COLLECTING DATA	RUNNING OPEN RANGE, B2,B3 BIDIRECTIONAL E/W	GPS	LINEAR	COOL	DRY	5
20030515	645	1600	OPEN RANGE	735	742	0	7	7	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL	DRY	5
20030515	645	1600	OPEN RANGE	742	750	0	8	8	2	COLLECTING DATA	RUNNING OPEN RANGE, B2,B3 BIDIRECTIONAL E/W	GPS	LINEAR	COOL	DRY	5
20030515	645	1600	OPEN RANGE	750	755	0	5	5	4	DOWNTIME DUE TO EQUIP FAILURE	GPS DOWN	GPS	NA	COOL	DRY	5
20030515	645	1600	OPEN RANGE	755	925	1	30	90	2	COLLECTING DATA	RUNNING OPEN RANGE, B2,B3 BIDIRECTIONAL E/W	GPS	LINEAR	COOL	DRY	5
20030515	645	1600	OPEN RANGE	925	945	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL	DRY	5
20030515	645	1600	OPEN RANGE	945	1140	1	55	115	2	COLLECTING DATA	RUNNING OPEN RANGE, B2,B3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1140	1150	0	10	10	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1150	1250	1		60	3	BREAK/LUNCH	CHOW	NA	NA	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1250	1255	0	5	5	1	SET-UP/ MOBILIZATION	SET UP ON C4,C5	NA	NA	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1255	1320	0	25	25	2	COLLECTING DATA	RUNNING OPEN RANGE, C4,C5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1320	1325	0	5	5	4	DOWNTIME DUE TO EQUIP FAILURE	COMMUNICATION ERROR INFIELD COMPUTOR	GPS	NA	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1325	1330		5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT FIELD COMPUTORS	GPS	NA	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1330	1530	2	0	120	2	COLLECTING DATA	RUNNING OPEN RANGE, C4,C5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	5
20030515	645	1600	OPEN RANGE	1530	1600	0	30	30	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	5
20030516	640	1600	OPEN RANGE	640	655	0	15	15	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	COOL	DRY	4

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20030516	640	1600	OPEN RANGE	655	700	0	5	5	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	COOL	DRY	4
20030516	640	1600	OPEN RANGE	700	825	1	25	85	2	COLLECTING DATA	RUNNING OPEN RANGE, C4,C5 BIDIRECTIONAL E/W	GPS	LINEAR	COOL	DRY	4
20030516	640	1600	OPEN RANGE	825	850	0	25	25	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	COOL	DRY	4
20030516	640	1600	OPEN RANGE	850	900	0	10	10	1	SET-UP/ MOBILIZATION	SET UP ON D3	NA	NA	COOL	DRY	4
20030516	640	1600	OPEN RANGE	900	1110	2	10	130	2	COLLECTING DATA	RUNNING OPEN RANGE, D3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1110	1125	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1125	1235	1	10	70	3	BREAK/LUNCH	CHOW	NA	NA	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1235	1330	0	55	55	2	COLLECTING DATA	RUNNING OPEN RANGE, D3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1330	1410	0	40	40	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1410	1515	1	5	65	2	COLLECTING DATA	RUNNING OPEN RANGE, D3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1515	1530	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030516	640	1600	OPEN RANGE	1530	1600	0	30	30	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	4
20030517	630	1430	OPEN RANGE	630	715	0	45	45	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	4
20030517	630	1430	OPEN RANGE	715	720	0	5	5	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	4
20030517	630	1430	OPEN RANGE	720	825	1	5	65	2	COLLECTING DATA	RUNNING OPEN RANGE, D2 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030517	630	1430	OPEN RANGE	825	921	0	56	56	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4

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20030517	630	1430	OPEN RANGE	921	1040	1	19	79	2	COLLECTING DATA	RUNNING OPEN RANGE, B5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030517	630	1430	OPEN RANGE	1040	1045	0	5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030517	630	1430	OPEN RANGE	1045	1120	0	35	35	3	BREAK/LUNCH	CHOW	NA	NA	HOT	DRY	4
20030517	630	1430	OPEN RANGE	1120	1230	1	10	70	2	COLLECTING DATA	RUNNING OPEN RANGE, B5 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	3
20030517	630	1430	OPEN RANGE	1230	1245	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030517	630	1430	OPEN RANGE	1245	1335	0	50	50	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	3
20030517	630	1430	OPEN RANGE	1335	1400	0	25	25	2	COLLECTING DATA	CONDUCTED EQUIPMENT INTERFERENCE TEST	GPS	NA	HOT	DRY	3
20030517	630	1430	OPEN RANGE	1400	1430	0	30	30	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	3
20030519	600	1430	OPEN RANGE	600	615	0	15	15	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	615	620	0	5	5	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	620	743	1	23	83	2	COLLECTING DATA	RUNNING OPEN RANGE, B4 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030519	600	1430	OPEN RANGE	743	815	0	32	32	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	815	930	1	15	75	2	COLLECTING DATA	RUNNING OPEN RANGE, B4 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030519	600	1430	OPEN RANGE	930	945	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	945	950	0	5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHANGE OUT BATTERY	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	950	955	0	5	5	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	4

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030519	600	1430	OPEN RANGE	955	1005	0	10	10	2	COLLECTING DATA	RUNNING OPEN RANGE, B4 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1005	1010	0	5	5	1	SET-UP/ MOBILIZATION	SET UP ON GRID C2,C3	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1010	1024	0	14	14	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1024	1130	1	6	66	2	COLLECTING DATA	RUNNING OPEN RANGE, C2,C3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1130	1145	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1145	1310	1	25	85	3	BREAK/LUNCH	CHOW/BREAK	NA	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1310	1410	1	0	60	2	COLLECTING DATA	RUNNING OPEN RANGE, C2,C3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1410	1420	0	10	10	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030519	600	1430	OPEN RANGE	1420	1430	0	10	10	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	530	545	0	15	15	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	545	549	0	4	4	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	549	718	1	29	89	2	COLLECTING DATA	RUNNING OPEN RANGE, C2,C3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030520	530	1310	OPEN RANGE	718	738	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	738	805	0	27	27	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	805	847	0	42	42	2	COLLECTING DATA	RUNNING OPEN RANGE, C2,C3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030520	530	1310	OPEN RANGE	847	900	0	13	13	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030520	530	1310	OPEN RANGE	900	937	0	37	37	2	COLLECTING DATA	RUNNING OPEN RANGE, C2,C3 BIDIRECTIONAL E/W	GPS	LINEAR	HOT	DRY	4
20030520	530	1310	OPEN RANGE	937	952	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030520	530	1310	OPEN RANGE	952	1012	0	20	20	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1012	1024	0	12	12	1	SET-UP/ MOBILIZATION	SET UP IN YUMA EXTREME	NA	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1024	1111	0	47	47	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1111	1130	0	19	19	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1130	1230	1	0	60	3	BREAK/LUNCH	LUNCH	NA	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1230	1245	0	15	15	1	SET-UP/ MOBILIZATION	SETUP	NA	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1245	1248	0	3	3	2	COLLECTING DATA	EQUIPMENT WAS CAL-BRATED USING CAL BALL	GPS	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1248	1255	0	7	7	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1255	1300	0	5	5	4	DOWNTIME DUE TO EQUIP FAILURE	FIELD COMPUTER OVERHEAT/FAILED	NA	NA	HOT	DRY	4
20030520	530	1310	YUMA EXTREME	1300	1310	0	10	10	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	4
20030521	530	1500	YUMA EXTREME	530	550	0	20	20	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	550	600	0	10	10	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	600	605	0	5	5	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	605	614	0	9	9	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030521	530	1500	YUMA EXTREME	614	750	1	36	96	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	750	810	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	810	820	0	10	10	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	820	850	0	30	30	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	YUMA EXTREME	850	920	0	30	30	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	920	930	0	10	10	1	SET-UP/ MOBILIZATION	SET UP IN MOGUL AREA	NA	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	930	1040	1	10	70	2	COLLECTING DATA	RUNNING MOGUL AREA, B-DIRECTIONAL N / SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1040	1100	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1100	1158	0	58	58	2	COLLECTING DATA	RUNNING MOGUL AREA, BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1158	1210	0	12	12	4	DOWNTIME DUE TO EQUIP FAILURE	GPS MOUNT BROKE, OPERATOR ERROR	NA	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1210	1230	0	20	20	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1230	1237	0	7	7	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1237	1322	0	45	45	2	COLLECTING DATA	RUNNING MOGUL AREA, BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1322	1335	0	13	13	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030521	530	1500	MOGUL AREA	1335	1445	1	10	70	2	COLLECTING DATA	RUNNING MOGUL AREA, BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030521	530	1500	MOGUL AREA	1445	1500	0	15	15	1	SET-UP/ MOBILIZATION	BREAKING DOWN EQUIPMENT EOD	NA	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	530	637	1	7	67	1	SET-UP/ MOBILIZATION	SETTING UP EQUIPMENT	NA	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	637	642	0	5	5	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	642	745	1	3	63	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	745	800	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	800	930	1	30	90	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	930	935	0	5	5	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	SWAP OUT BATTERIES	NA	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	935	950	0	15	15	2	COLLECTING DATA	RUNNING YUMA EXTREME BIDIRECTIONAL NORTH/SOUTH	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	950	1005	0	15	15	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030522	530	1500	YUMA EXTREME	1005	1020	0	15	15	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1020	1028	0	8	8	1	SET-UP/ MOBILIZATION	SET UP OVER CALIBRATION PIT	NA	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1028	1030	0	2	2	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1030	1052	0	22	22	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 40MM MARK II	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1052	1105	0	13	13	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 57MM	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1105	1128	0	23	23	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 60MM	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1128	1138	0	10	10	3	BREAK/LUNCH	BREAK	NA	NA	HOT	DRY	3

Date	Start-Time	Stop-Time	Area Tested	Status Start Time	Status Stop Time	hr	min	Duration, min	Op Stat Code	Operational Status	Operational Status-Comments	Track Method	Pattern	Field Conditions		No. of People
20030522	530	1500	CALIBRATION PIT	1138	1149	0	11	11	5	DOWNTIME DUE TO EQUIP MAINT/CHECK	CHECKING/ DOWNLOADING DATA	GPS	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1149	1240	0	51	51	3	BREAK/LUNCH	LUNCH	NA	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1240	1243	0	3	3	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1243	1255	0	12	12	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON ROCKEYE MK118	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1255	1320	0	25	25	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 2.75 ROCKET	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1320	1347	0	27	27	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 105 STANDARD	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1347	1412	0	25	25	2	COLLECTING DATA	RUNNING SIGNITURE DATA ON 155MM	GPS	LINEAR	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1412	1414	0	2	2	2	COLLECTING DATA	EQUIPMENT WAS CALIBRATED USING CAL BALL	GPS	NA	HOT	DRY	3
20030522	530	1500	CALIBRATION PIT	1414	1500	0	46	46	7	DEMOBILIZATION	END OF TEST	NA	NA	HOT	DRY	3

Appendix C: Soil Analysis

http://aec.army.mil/usaec/technology/uxo-soilanalysis.pdf

Table C1. Laboratory tests performed on soil samples.

Sample	Water Content	Sieve/Hydrometer	Magnetic Susceptibility	Dielectric Permittivity	X-Ray Diffraction
Y-CA-SS1 to Y-CA-SS3	X	X	X		
Y-EA-SS1 to Y-EA-SS2	X	X	X		
Y-MA-SS1 to Y-MA-SS2	X	X	X		
Y-OR-SS1 to Y-OR-SS3	X	X	X		
13 Soil cores			X		
Y-BL-1* Y-CA-1* Y-EA-1*, Y-EA-2* Y-MA-1*, Y-MA-2* Y-OR-1 to Y-OR-7* 0.05m	X	X	X	X*	
0.25m	X	X	X		
0.50m	X	X	X	X	
1.00m	X	X	X	X	
1.50m	X	X	X		
2.00m	X	X	X	X	
2.50m	X	X	X		
3.00m	X	X	X	X	
Y-OR-3 2.00m					X
Y-OR-5 1.00m					X
Y-OR-5 2.50m					X
Y-OR-5 3.00m					X

* Exceptions to laboratory Tests
Y-BL-1: no dielectric permittivity measurement at 3.00 m (insufficient soil recovery)
Y-CA-1: no dielectric permittivity measurement at 1.00 m (insufficient soil recovery)
Y-EA-1: no water content at 0.5 m; no mag. susceptibility at 0.25 m; no dielectric perm. at 0.5 m
Y-EA-2: no soil recovery above 1.00 m
Y-OR-2: end of push at 2.00 m
Y-OR-3: no measurements at 0.25, 0.50 m (insufficient soil recovery)
Y-EA-2, Y-MA-2, Y-OR-1, Y-OR-4, Y-OR-5, Y-OR-6: no 5-cm dielectric permittivity measurement.

Table C2. Summary of sieve and hydrometer analysis, surface samples.

Sample	Depth (m)	Visual Classification	Color	% Gravel	%Sand	%Fines	Specific Gravity of Solids	% Water Content
Calibration								
Y-CA-551	Surface	Gravelly silty sand	Brown	41.7	41.8	16.6	2.67	0.6
Y-CA-552	Surface	Gravelly clay sand	Brown	28.5	41.1	30.4	2.67	1.0
Blind								
Y-CA-553	Surface	Gravelly clay sand	Brown	33.7	38.5	27.7	2.67	0.8
Extreme								
Y-EA-551	Surface	Sandy silty gravel	Brown	59.9	30.1	10.1	2.67	0.5
Y-EA-552	Surface	Gravelly silty sand	Brown	32.4	52.4	15.2	2.67	0.5
Mogul								
Y-MA-551	Surface	Gravelly silty sand	Brown	24.1	41.0	35.0	2.67	0.5
Y-MA-552	Surface	Sandy silty gravel	Brown	41.5	26.0	32.5	2.67	0.5
Open Range								
YY-CR-551	Surface	Gravelly silty sand	Brown	40.2	48.2	11.6	2.67	0.5
YY-CR-552	Surface	Gravelly silty sand	Brown	36.2	47.6	17.1	2.67	0.6
YY-CR-553	Surface	Gravelly silty sand	Brown	15.5	58.0	26.5	2.67	0.6
YY-CR-554	Surface	Gravelly silty sand	Brown	17.3	40.5	42.3	2.67	0.9
YY-CR-555	Surface	Sandy silty gravel	Brown	44.8	24.6	30.6	2.67	0.9
YY-CR-556	Surface	Gravelly silty sand	Brown	26.5	38.7	33.8	2.67	0.7
YY-CR-557	Surface	Gravelly clay sand	Brown	27.1	46.5	26.4	2.67	0.7
YY-CR-558	Surface	Gravelly silty sand	Brown	27.0	31.6	41.5	2.67	0.9

Appendix D: Definitions from ATC Web site

Anomaly	Location of a system response deemed to warrant further investigation by the demonstrator for consideration as an emplaced ordnance item.
Azimuth	Positive clockwise direction of the ordnance nose from magnetic North.
BA^{disc}	A discrimination-stage location outside R_{halo} of any emplaced ordnance or emplaced clutter item.
BAR^{disc}	= (# of BA^{disc})/(test area).
BA^{res}	An anomaly from the response stage outside R_{halo} of any emplaced ordnance or emplaced clutter item.
BAR^{res}	= (# of BA^{res})/(test area).
Blind Test Grid	A matrix of squares. Center of each grid block may be a target, a piece of clutter, or nothing to test demonstrator detection system performance.
Calibration Lane	Contains targets from the standardized target list at 7 primary orientations to allow the demonstrator to develop a library on his detection system performance against known targets and location.
Clutter	Clutter items may include fragments of military munitions which have functioned as designed or were recovered from areas where munitions have been intentionally destroyed and have no explosive, pyrotechnic or chemical filler; steel; aluminum; magnetic rock; or copper.
Degaussing	Removing any remnant magnetic moments from ordnance targets.
Demonstrator	Vendor, user, developer of UXO detection and discrimination technologies.
Detection	An anomaly location that is within R_{halo} of an emplaced ordnance item.
Dip	Angle of inclination; Nose up (+), Nose down (-).
Discrimination	The application of a signal processing algorithm or human judgment to response-stage data that discriminates ordnance from clutter.

Discrimination Stage	The ability to correctly identify ordnance as such, and to reject clutter. For the same locations as in the RESPONSE STAGE anomaly column, the DISCRIMINATION STAGE column contains the output of the algorithms applied in the discrimination-stage processing. This column is prioritized based on the determination that an anomaly location is likely to contain ordnance. Thus, higher output values are indicative of higher confidence that an ordnance item is present at the specified location. For electronic signal processing, priority ranking is based on algorithm output. For other systems, priority ranking is based on human judgment. The demonstrator also selects the threshold that provides optimum system performance, (i.e., that retains all the detected ordnance and rejects the maximum amount of clutter).
Efficiency (E)	$= P_{det}^{disc}(t^{disc})/P_{det}^{res}(t_{min}^{res})$; Measures (at a threshold of interest), the degree to which the maximum theoretical detection performance of the sensor system (as determined by the response stage t_{min}) is preserved after application of discrimination techniques. Efficiency is a number between 0 and 1. An efficiency of 1 implies that all of the ordnance initially detected in the response stage was retained at the specified threshold in the discrimination stage, t^{disc}.
Emplaced Clutter	A clutter item (i.e., nonordnance item) buried by the government at a specified location in the test site.
Emplaced Ordnance	An inert ordnance item buried by the government at a specified location in the test site.
FAR	False identification of target in a empty grid cell.
FAR^{res}	= (# of BA^{res})/(# of opportunities).
fp^{disc}	A discrimination-stage location within R_{halo} of an emplaced clutter item.
fp^{res}	An anomaly location that is within R_{halo} of an emplaced clutter item.
Large Ordnance	Caliber of ordnance greater than 81-mm (includes 105-mm HEAT, 105-mm projectile, 155-mm projectile, 500-lb bomb).
Medium Ordnance	Caliber of ordnance greater than 40-mm and less than or equal to 81-mm (includes 57-mm projectile, 60-mm mortar, 2.75-inch Rocket, MK 118 Rockeye, 81-mm mortar).

NAD83 Datum	Expressed as an Easting/Northing UTM number.
Open Field Site	Minimum 4 hectares site with a myriad of clutter, range simulations, and targets to test demonstrator detection system performance under real field-type conditions.
P_{ba}^{disc}	= (# of BA^{disc})/(# of empty grid locations).
P_{det}^{disc}	= (# of discrimination-stage detections)/(# of emplaced ordnance in the test site).
P_{det}^{res}	= (# of response-stage detections)/(# of emplaced ordnance in the test site).
P_{fp}^{res}	= (# of response-stage false positives)/(# of emplaced clutter items).
R_{BA}	= 1 - [$BAR^{disc}(t^{disc})/BAR^{res}(t_{min}^{res})$]; Measures the degree to which the discrimination stage correctly rejects background alarms initially detected in the response stage. The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all background alarms initially detected in the response stage were rejected at the specified threshold in the discrimination stage.
R_{fp}	= 1 - [$P_{fp}^{disc}(t^{disc})/P_{fp}^{res}(t_{min}^{res})$]; Measures (at a threshold of interest), the degree to which the sensor system's false positive performance is improved over the maximum false positive performance (as determined by the response stage tmin). The rejection rate is a number between 0 and 1. A rejection rate of 1 implies that all emplaced clutter initially detected in the response stage were correctly rejected at the specified threshold in the discrimination stage.
R_{halo}	A predetermined radius about the center of the periphery of an emplaced item (clutter or ordnance) within which a location identified by the demonstrator as being of interest is considered to be a response from that item. If multiple declarations lie within R_{halo} of any item (clutter or ordnance), the declaration with the highest signal output within the R_{halo} is utilized.
Raw Sensor Data	Preprocessed or minimally processed data for each grid square or open field area.

Response Stage	The ability of the demonstrator's system to detect emplaced targets without regard to ability to discriminate ordnance from other anomalies. The RESPONSE STAGE provides the location and signal strength of all anomalies deemed sufficient to warrant further investigation and/or processing as potential emplaced ordnance items. This list is generated with minimal processing (e.g., this list will include all signals above the system noise threshold). As such, it represents the most inclusive list of anomalies.
ROC Curve	Receiver Operating Characteristic curve provides the only useful and valid means of comparing performance among sensor/algorithm combinations and for determining the efficacy of algorithm or technology advancements.
Small Ordnance	Caliber of ordnance less than or equal to 40-mm (includes 20-mm projectile, 40-mm projectile, submunitions BLU-26, BDU-28, and M42).
Standardized Site	Made up of three areas - Calibration Lanes/Ground Test Pit, a Blind Test Grid, and an Open Field Site designed to test the demonstrator detection systems under various test parameters.
Standardized Target	A military munition which contains no energetic material. These items pose no imminent threat. However, will remain under the control of the Standardized UXO Technology Demonstration Site On-Site Project Manager as issued by the ATC Project Manager.
Threshold	The limit, set on a system's discrimination stage, which defines the difference between what is considered to be ordnance and what is considered nonordnance. Only those signals that exceed (or fall below, depending on the signal strength polarity) the threshold are considered to result from ordnance.
Target Repository	Located at Aberdeen Proving Ground, MD. Managed by the ATC Target Repository Standardized UXO Technology Demonstration Site Program Manager. Thirteen types of standardized targets are available for loan.

Unexploded Ordnance (UXO)	A military munition that contains explosive or pyrotechnic charge and has been primed, fuzed, armed or otherwise prepared for action and which has been fired, placed, dropped, launched or projected, and remains unexploded by design or malfunction. An item of explosive ordnance which has failed to function as designed or has been abandoned, discarded or improperly disposed of and is still capable of functioning, causing damage to personnel or material. These can be, but are not limited to high-explosive warheads, rocket motors, practice munitions with spotting charges, torpedoes, artillery and mortar ammunition, grenades, incendiary munitions, electro-explosive devices and propellant-actuated devices. Fuzes with live explosive boosters or detonators are classified as UXO. All UXO are potentially dangerous and cannot be released for public use without being rendered safe (neutralized, vented, detonated, decontaminated or demilitarized).

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
November 2007	Final report	

4. TITLE AND SUBTITLE

Yuma Proving Ground GEM-3-E Data Collection

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Hollis H. "Jay" Bennett, Jr., Tere A. DeMoss, Morris P. Fields,
Ricky A. Goodson, Charles D. Hahn, and John Cliff Morgan

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/EL TR-07-28

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report documents the performance and operational capabilities of the GEM-3 system for the Advanced UXO Detection/ Discrimination Technology Demonstration at the U.S. Army Yuma Proving Ground (YPG), Yuma, AZ. The data collection effort was conducted under the Department of the Army Research and Development DOBE4 (BA4) Technical Demonstration Program. Data analysis was conducted under the Department of the Army Research and Development DOE3 (BA3) Program. The objective was to evaluate the enhancements made to the GEM-3 system. Post-demonstration analysis focused on the functionality of the sensor system, the evaluation of the noise level of the data collected, improvements in target detection and discrimination, and positioning accuracy of the system. The stability of the system was evaluated through histograms and statistical analysis of data collected during the technology demonstration. Based on findings of the characteristics of the collected data and initial work performed on target detection and discrimination, target detection and discrimination techniques were applied and evaluated.

15. SUBJECT TERMS

See reverse.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		68	

15. SUBJECT TERMS

Aberdeen Testing Center (ATC)
Electromagnetic induction (EMI)
EMI sensor
Frequency domain electromagnetic (FDEM)
Geophex, Ltd.
Unexploded ordnance (UXO)
YPG Standardized UXO Technology Demonstration Site
Yuma Proving Ground (YPG)